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Fujisawa

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(54) **TIMEPIECE WITH WIRELESS COMMUNICATION FUNCTION**

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G04C 11/02 (2006.01)

(52) **U.S. Cl.**
USPC **368/47**

(58) **Field of Classification Search**
USPC 368/47, 296
See application file for complete search history.

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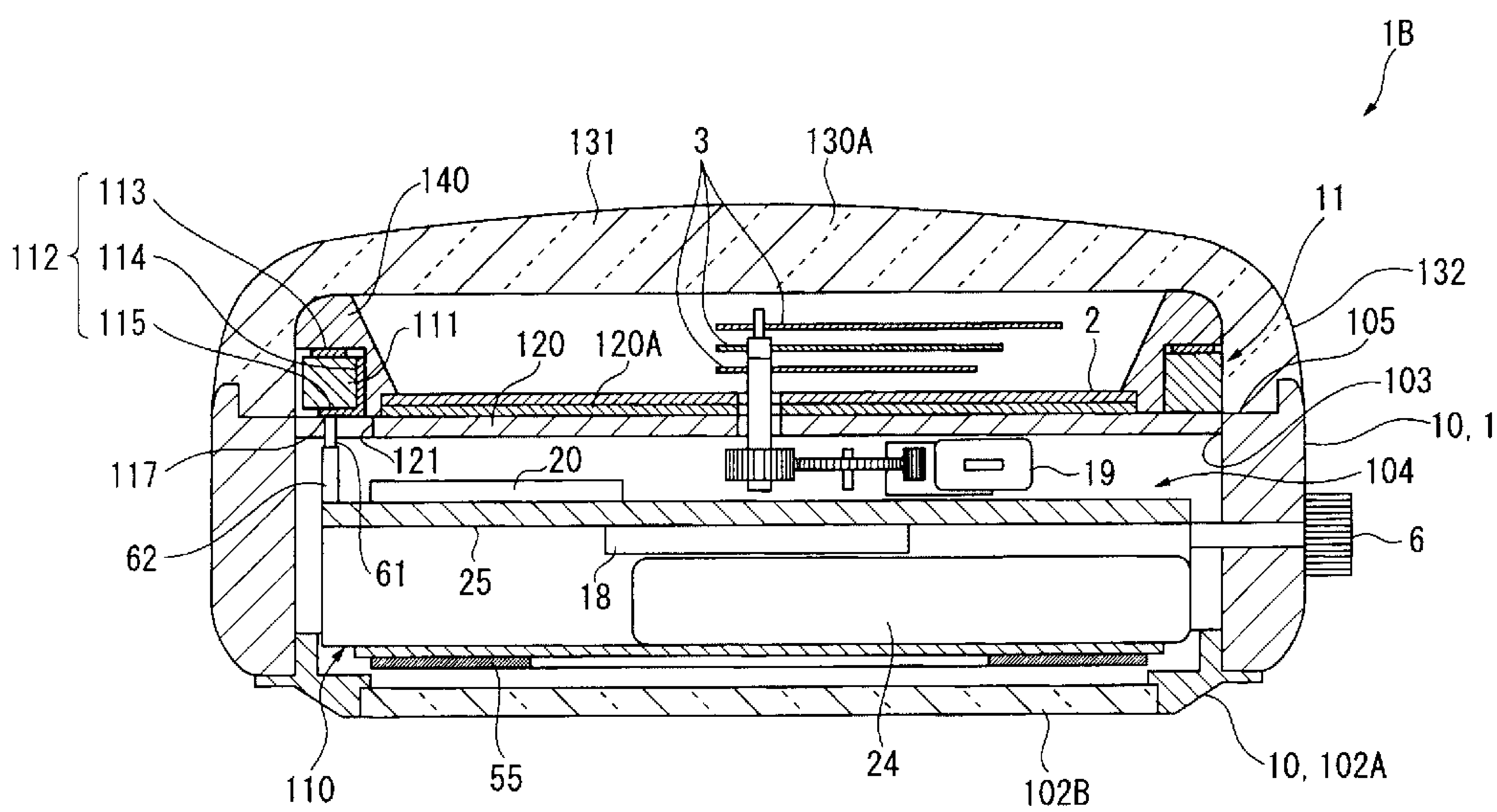
Primary Examiner — R S Luebke
Assistant Examiner — Jason Collins

(57) **ABSTRACT**

A timepiece with a wireless function, including a movement for displaying time; a conductive case that holds the movement; a crystal that is disposed on the face side of the case and covers the face side of the movement; a conductive plate that is electrically conductive, disposed between the movement and the crystal, and reflects radio waves; and an antenna that has a substantially annular, conductive antenna electrode, and is disposed along the outside edge of the conductive plate between the conductive plate and the crystal.

10 Claims, 12 Drawing Sheets



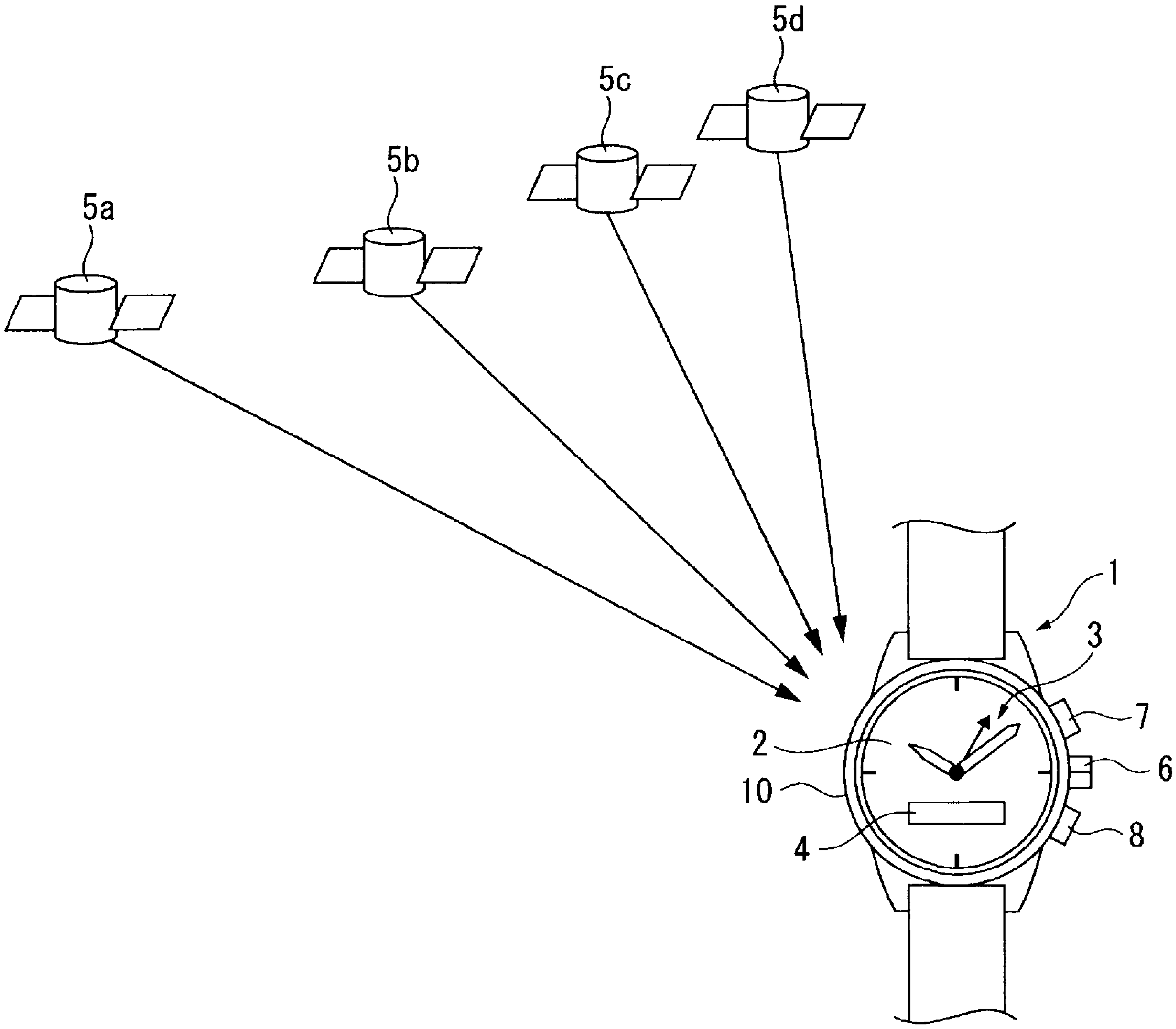


FIG. 1

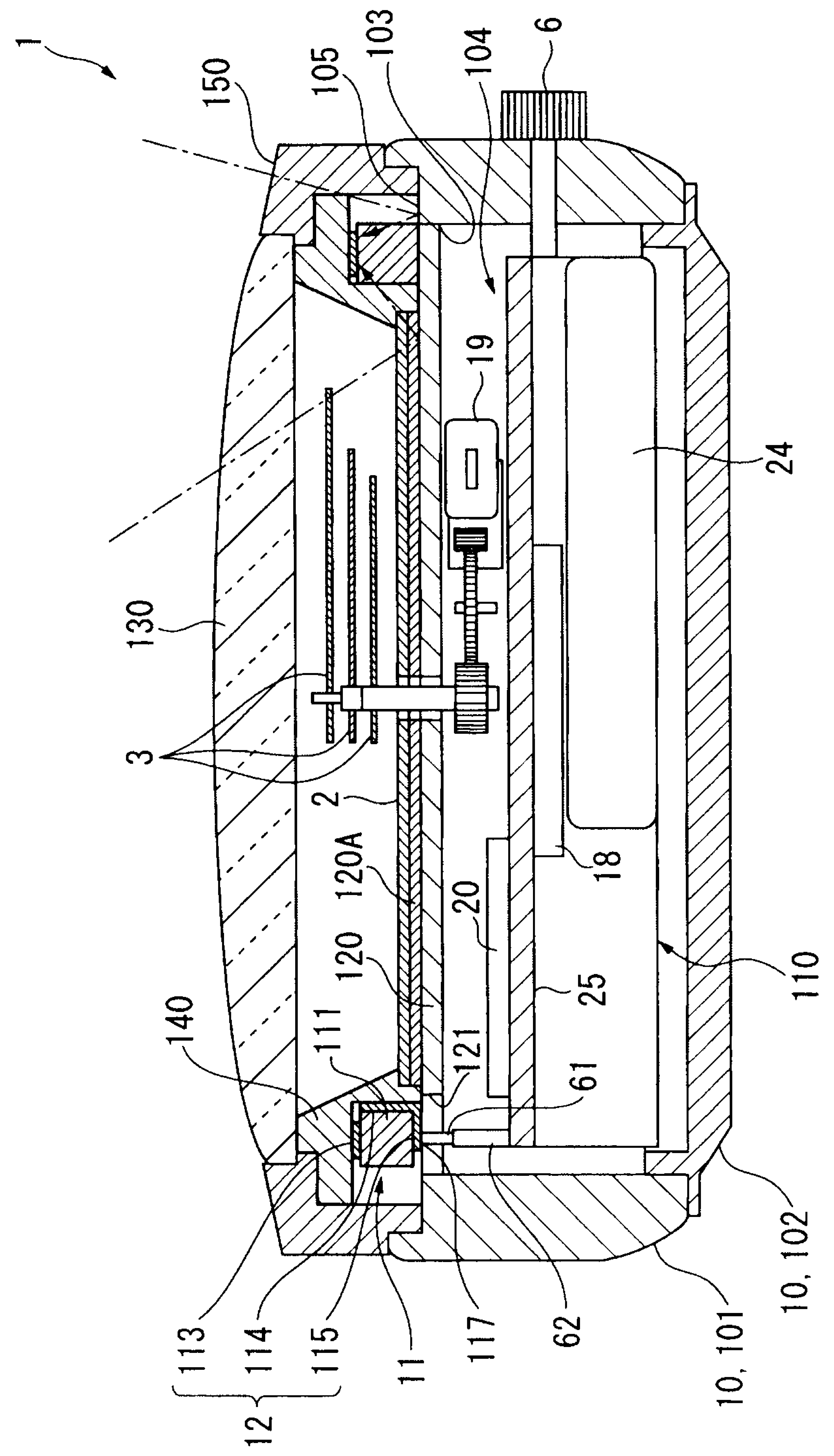

1
150
105
103
104
6
19
24
130
3
2
120A
120
20
18
25
110
140
111
121
61
113
114
115
11
117
62
10, 101
10, 102
112

FIG. 2

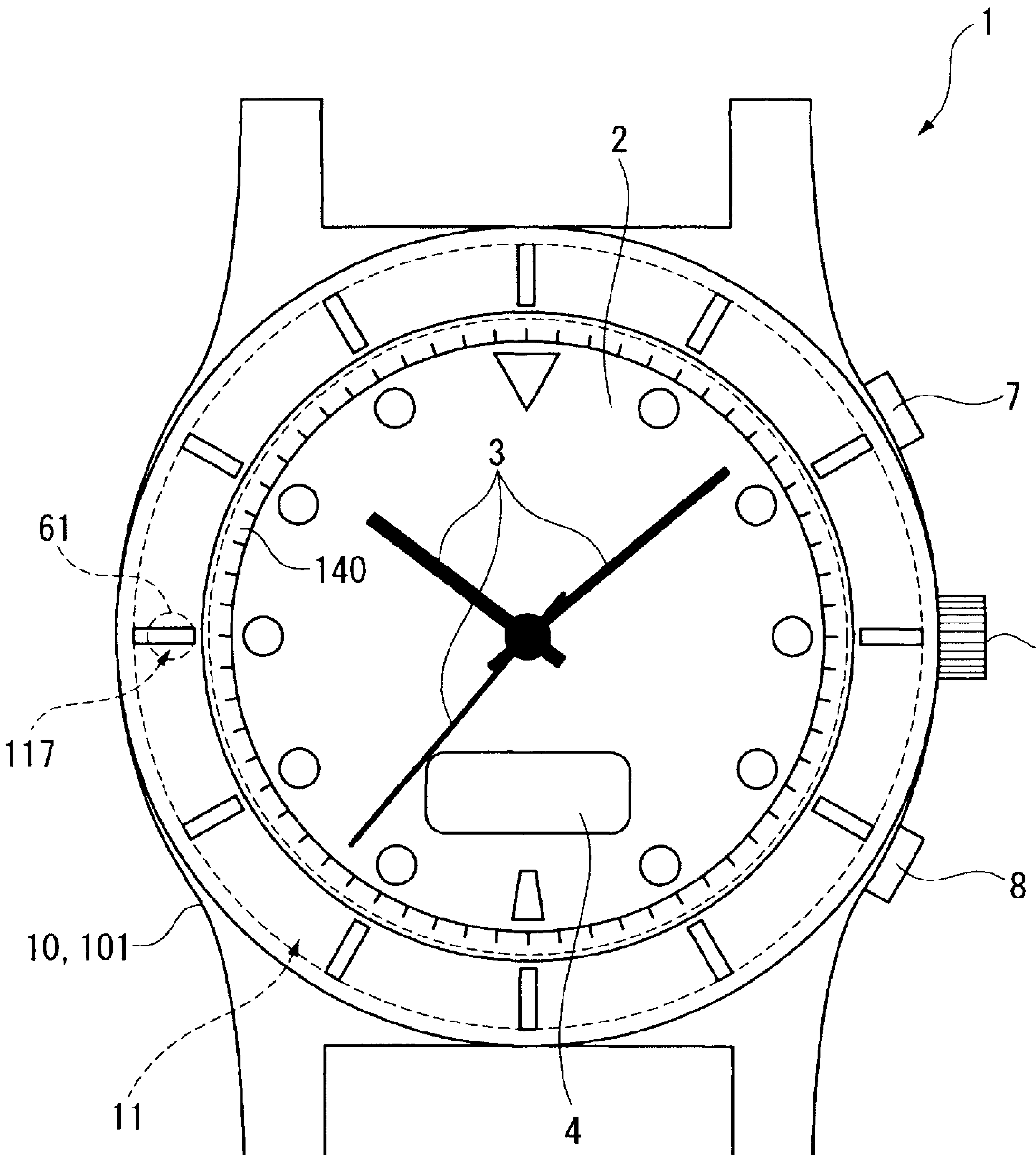
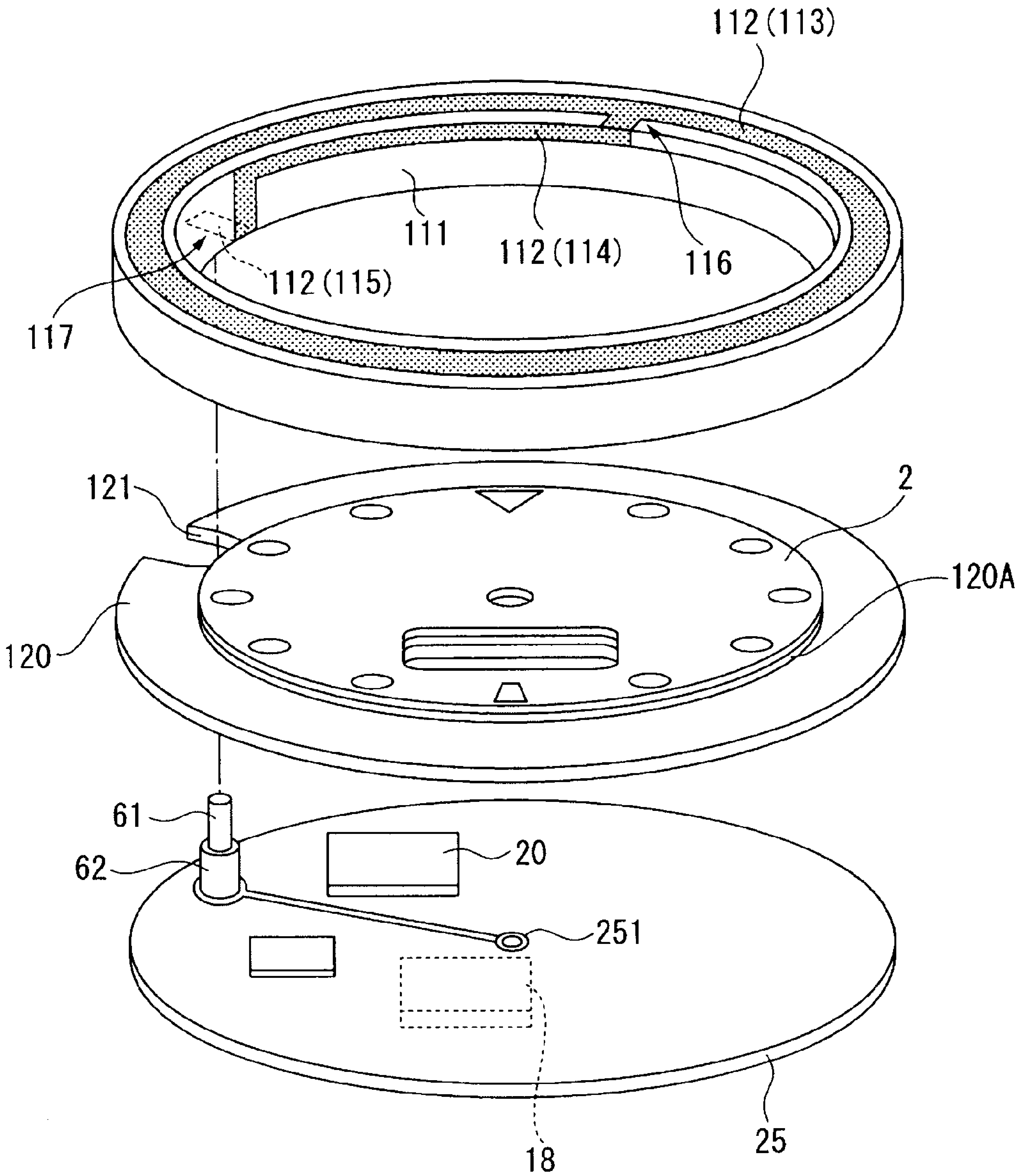


FIG. 3



112 (113)
111
112 (114)
116
112 (115)
117
121
2
120A
120
61
20
62
251
25
18

FIG. 4

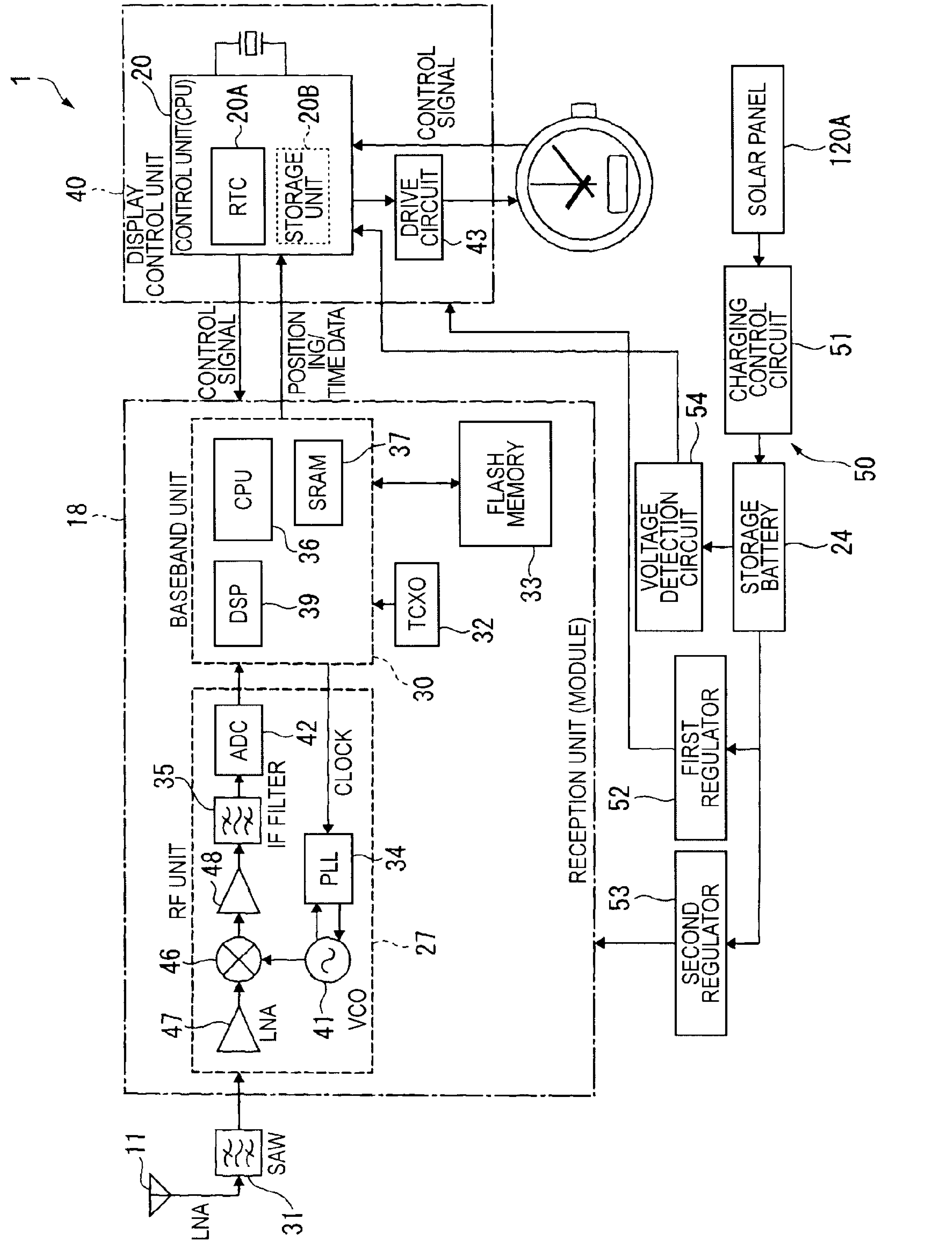

1
40
DISPLAY CONTROL UNIT
20
CONTROL UNIT(CPU)
20A
RTC
20B
STORAGE UNIT
CONTROL SIGNAL
DRIVE CIRCUIT
43
SOLAR PANEL
120A
CONTROL SIGNAL
POSITIONING/ TIME DATA
CHARGING CONTROL CIRCUIT
51
50
54
VOLTAGE DETECTION CIRCUIT
STORAGE BATTERY
24
18
BASEBAND UNIT
CPU
36
SRAM
37
FLASH MEMORY
33
DSP
39
TCXO
32
30
RECEPTION UNIT (MODULE)
FIRST REGULATOR
52
SECOND REGULATOR
53
ADC
42
CLOCK
35
IF FILTER
RF UNIT
48
PLL
34
46
27
47
LNA
41
VCO
11
LNA
SAW
31

FIG. 5

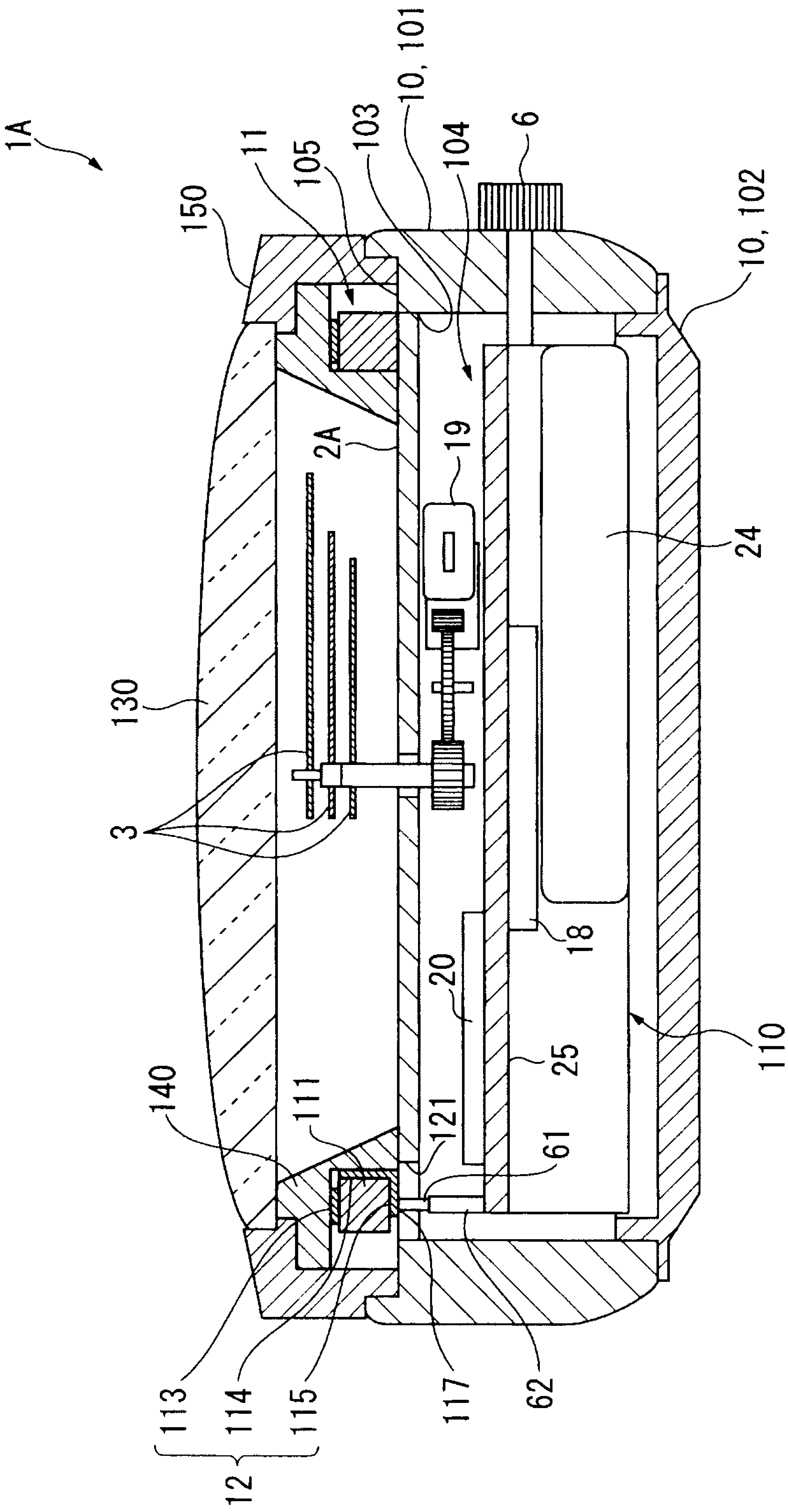

1A
150
11
105
103
10, 101
104
6
10, 102
2A
19
24
130
3
18
20
25
110
140
111
121
61
113
114
115
117
62
112

FIG. 6

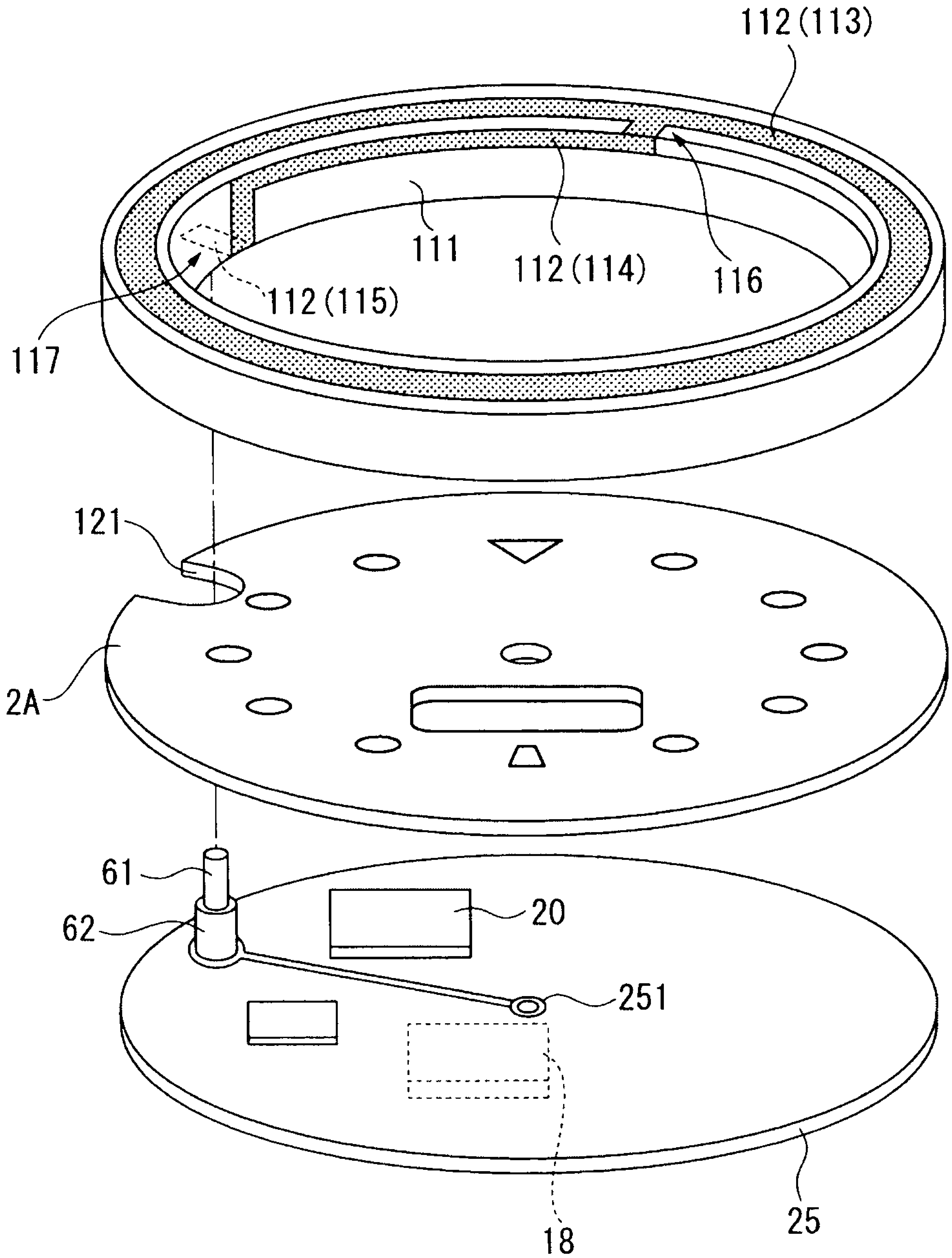


FIG. 7

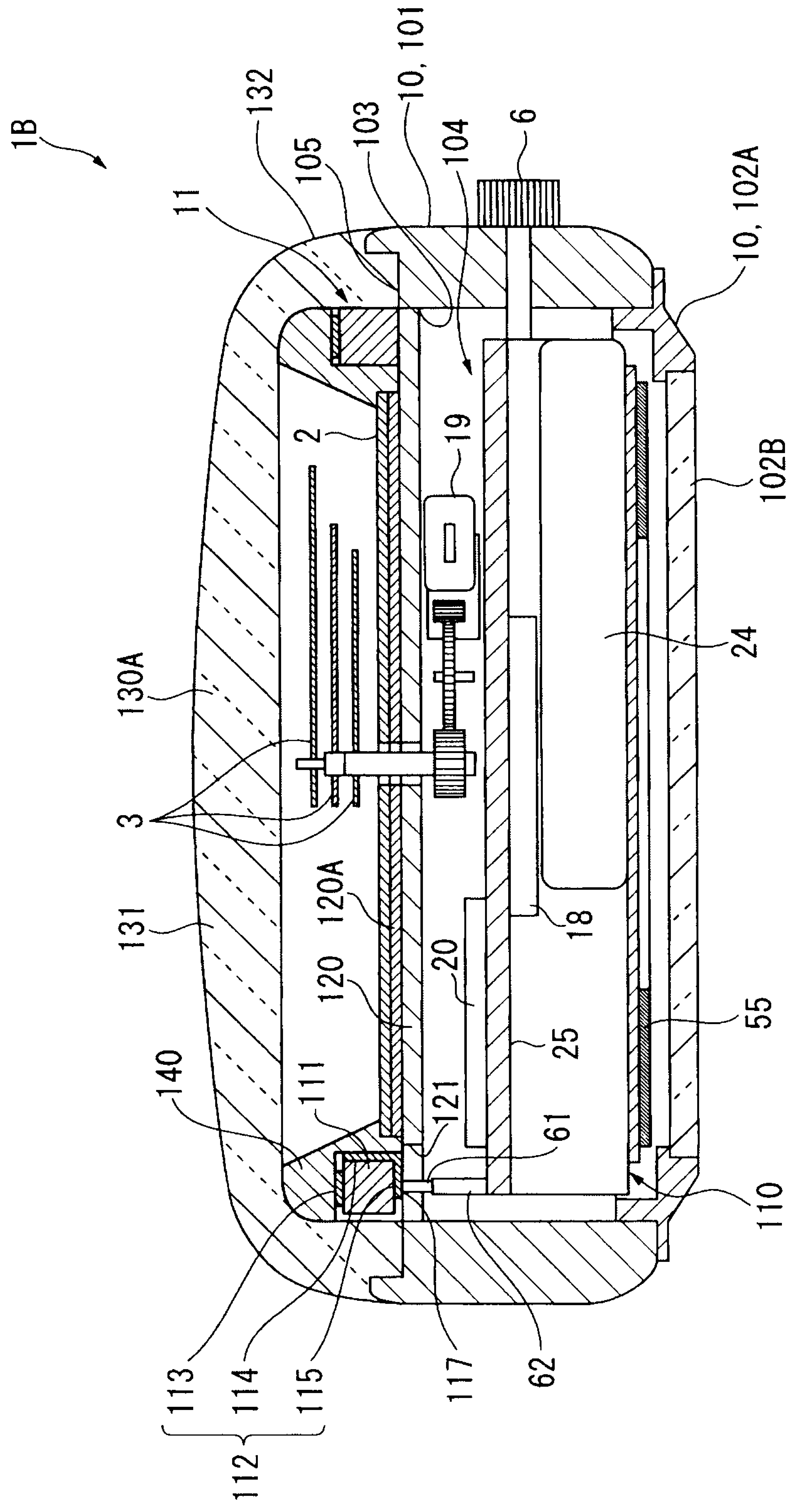

1B
11
132
105
103
10, 101
104
6
10, 102A
2
19
102B
24
130A
3
131
120A
120
20
18
25
55
140
111
121
61
110
113
114
115
117
62
112

FIG. 8

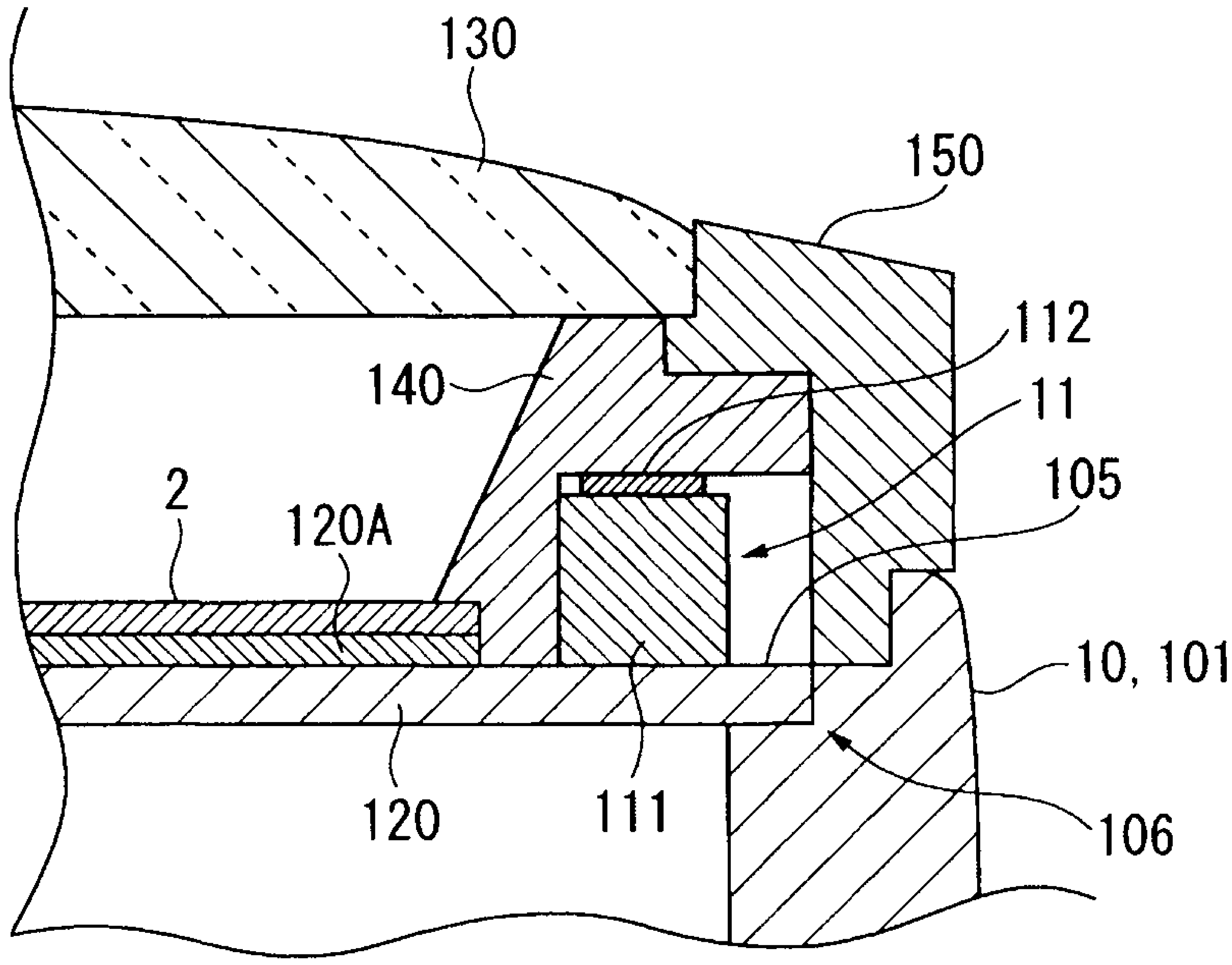

130
150
112
140
11
105
2
120A
10, 101
120
111
106

FIG. 9A

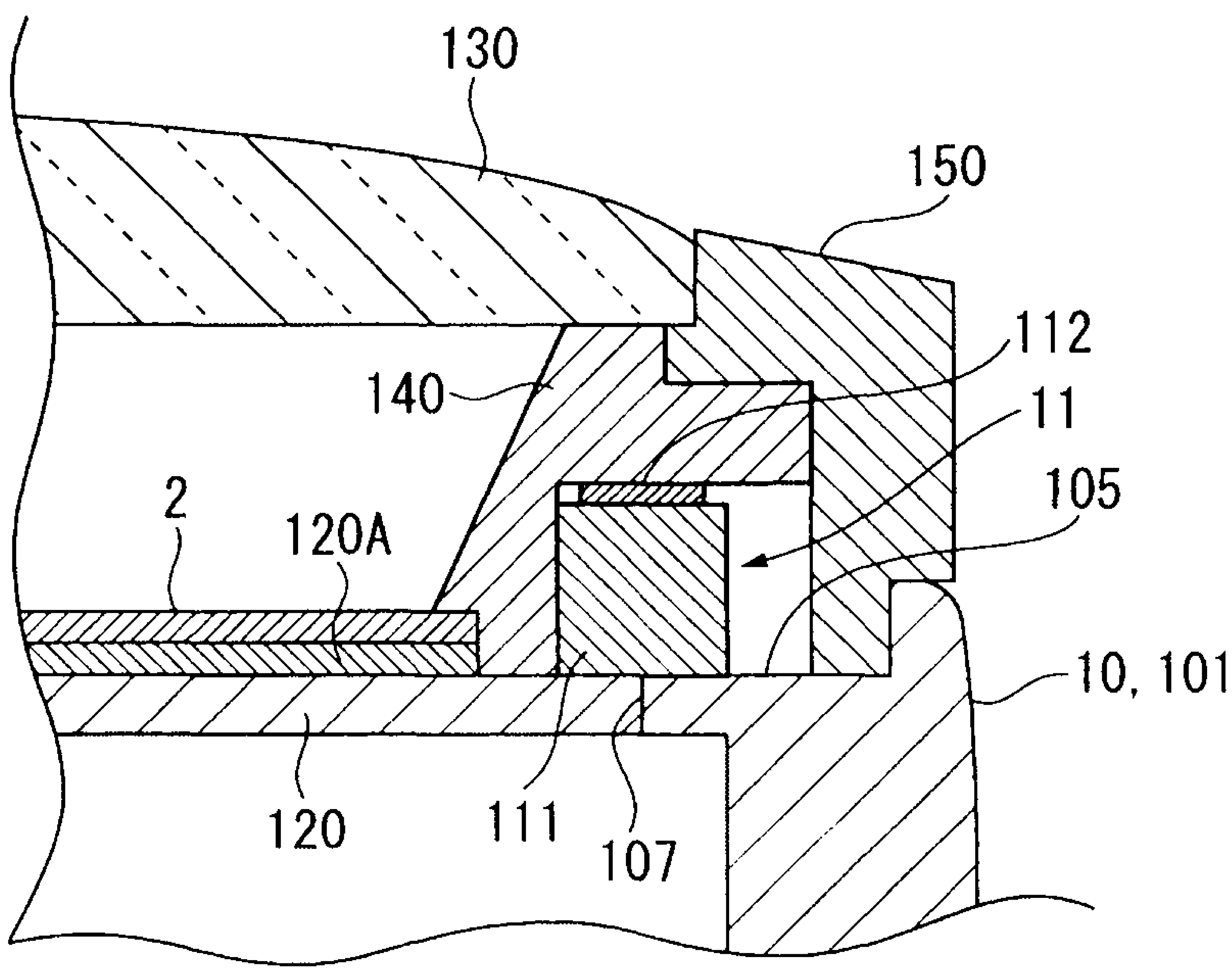

130
150
112
140
11
105
2
120A
10, 101
120
111
107

FIG. 9B

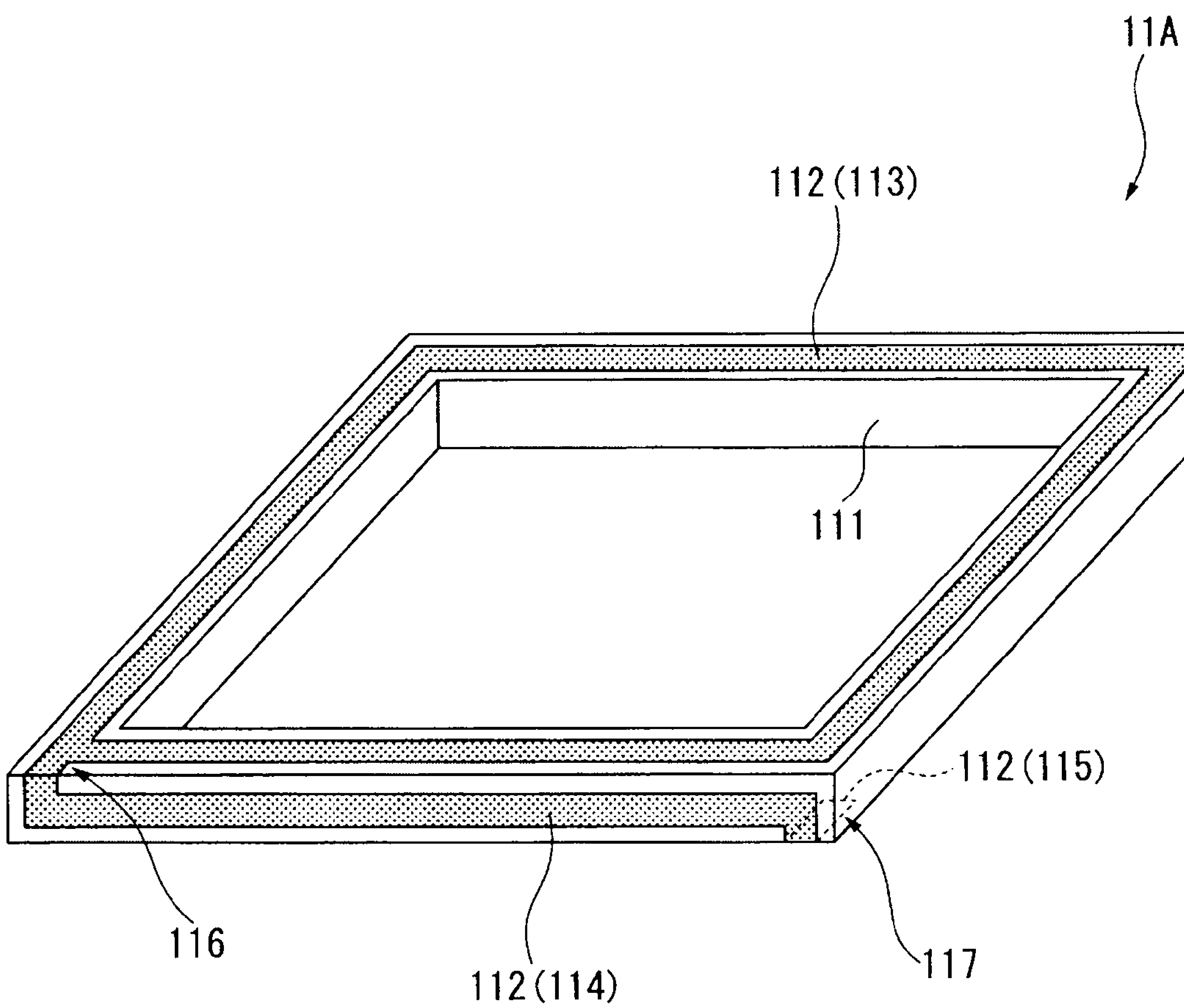


FIG.10

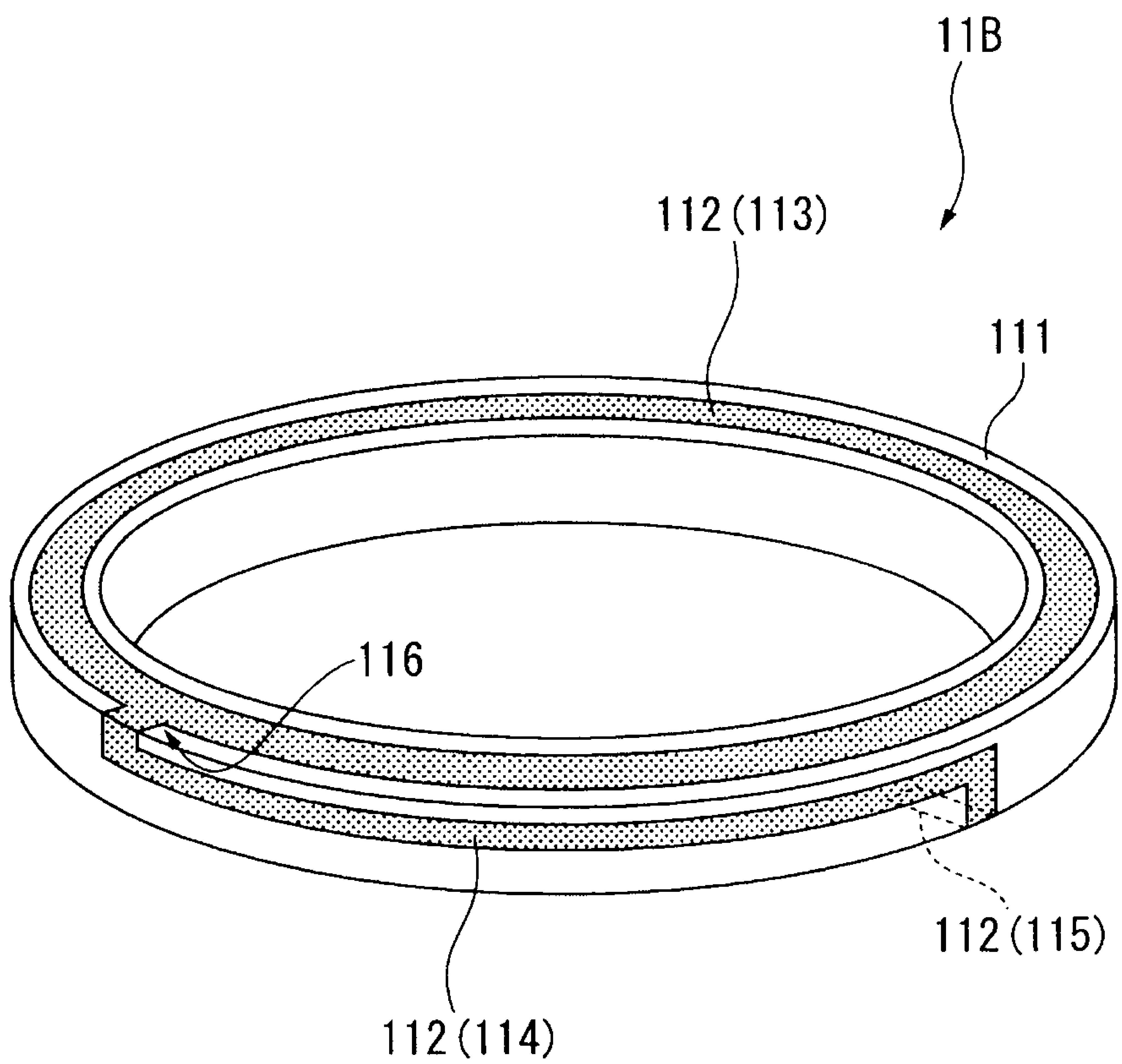


FIG.11

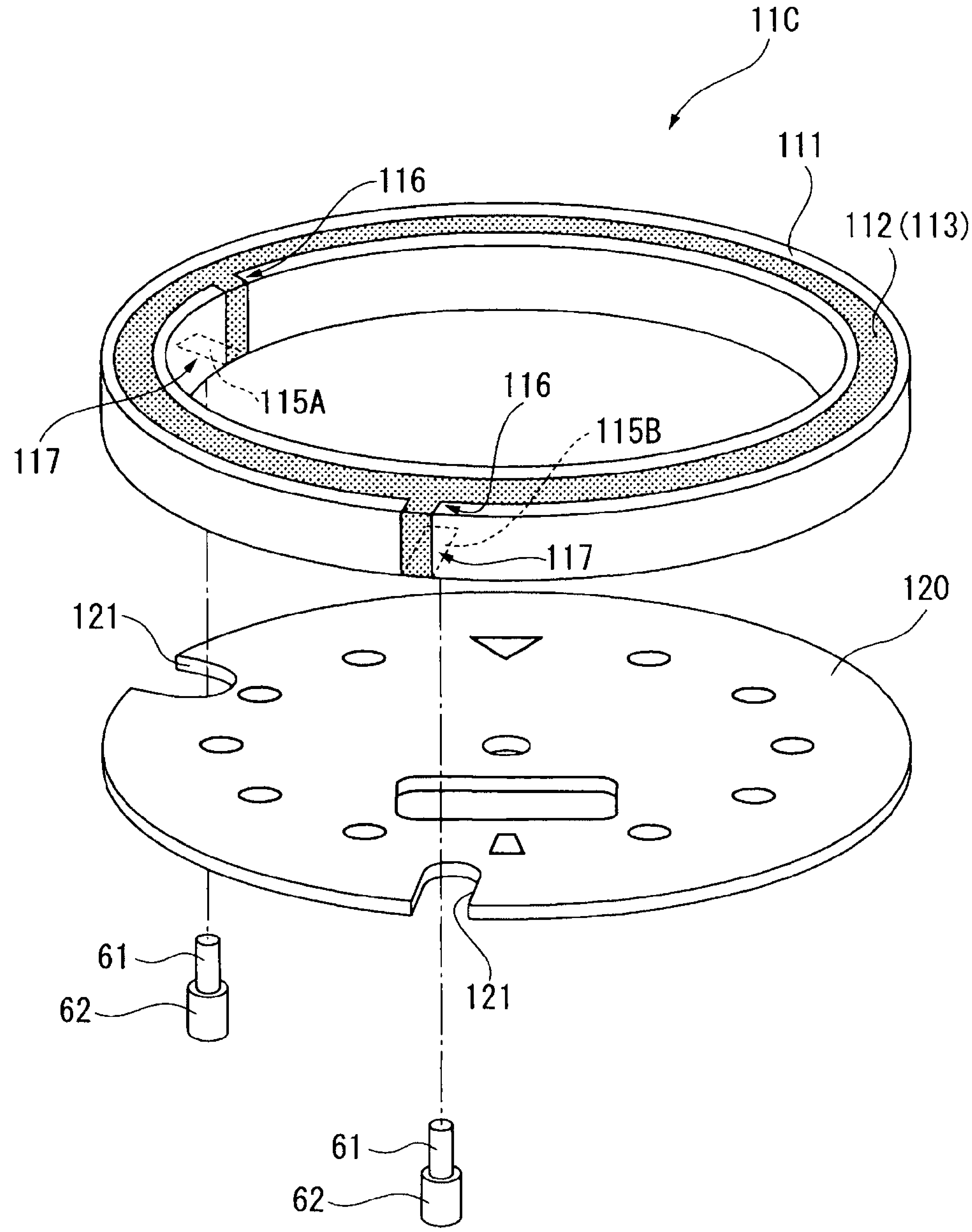


FIG.12

TIMEPIECE WITH WIRELESS COMMUNICATION FUNCTION

CROSS-REFERENCE TO RELATED APPLICATION

Japanese Patent application No. 2009-165503 is hereby incorporated by reference in its entirety.

BACKGROUND

1. Field of Invention

The present invention relates to a timepiece with a wireless communication function for receiving radio frequency signals.

2. Description of Related Art

Timepieces that have a wireless communication function are known from the literature. One use for such wireless communication functions is receiving signals from positioning information satellites such as GPS (Global Positioning System) satellites to detect the current position.

When a wireless communication function is rendered in a wristwatch as such a timepiece with a wireless communication function, an antenna with sufficient reception performance must be rendered in a confined space.

Wristwatches that can function as a reception terminal in a satellite communication system, and wristwatches with a function for sending and receiving RF transmission signals, are taught in Japanese Unexamined Patent Appl. Pub. JP-A-2000-59241, Japanese Unexamined Patent Appl. Pub. JP-A-2001-27680, and Japanese Unexamined Patent Appl. Pub. JP-A-H10-160872.

In the wristwatch taught in JP-A-2000-59241, a C-shaped loop antenna with a dielectric substrate is disposed around the display unit, and the metal case member of the wristwatch is used as a ground plate.

In the wristwatch taught in JP-A-2001-27680, a GPS antenna is disposed beside the display unit of the wristwatch. The GPS antenna is affixed to the metal wristwatch case with double-sided tape.

In the wristwatch taught in JP-A-H10-160872, the antenna and communication circuit are together rendered in a plastic bezel, and a communication mechanism can be easily added to the wristwatch by simply installing the bezel. The antenna is covered by the bezel and cannot be seen from the outside.

In addition to practical functions such as displaying the time and communication functions, a high quality appearance is also desirable in a timepiece. This is particularly true for analog wristwatches.

Metal materials with a precision finish are commonly used for the case, dial, and other external parts of such timepieces. Functional elements such as communication antennas in particular must be covered or rendered internally so that they do not detract from the external appearance.

With the timepieces taught in JP-A-2000-59241 and JP-A-2001-27680, the communications antenna is large and exposed beside the display unit, and cannot be used if a quality appearance is also a consideration.

The configuration taught in JP-A-H10-160872 largely obviates appearance-related problems, but cannot assure sufficient antenna performance. More specifically, the communications antenna is not exposed but a ground plate cannot be assured.

In addition, while a metal case and dial are desirable for appearance considerations, their conductivity also makes them function as an electromagnetic shield blocking RF signals from the inside. As a result, when the antenna is disposed inside a metal case and dial, sufficient antenna performance cannot be achieved.

SUMMARY OF INVENTION

A timepiece with a wireless function according to the present invention can simultaneously assure a good appearance and good antenna performance.

A first aspect of the invention is a timepiece with a wireless function, including a movement for displaying time; a conductive case that holds the movement; a crystal that is disposed on the face side of the case and covers the face side of the movement; a conductive plate that is electrically conductive, disposed between the movement and the crystal, and reflects radio waves; and an antenna that has a substantially annular, conductive antenna electrode, and is disposed along the outside edge of the conductive plate between the conductive plate and the crystal.

The substantially annular antenna electrode of the antenna includes both ring-shaped antenna electrodes and antenna electrodes of which part of the ring is missing, such as a C-shaped antenna electrode.

In this aspect of the invention a conductive plate is disposed on the face side of the timepiece that is covered by the crystal, such as where the dial appears in a normal wristwatch design. Particularly with a wristwatch, the case is preferably metal to improve the appearance of the timepiece. Such a configuration impedes the input of RF signals from the sides and back cover parts of the timepiece, and RF signals can only enter from the crystal side. By disposing the conductive plate on the face side of the timepiece where the crystal is located, input RF signals can be reflected to the antenna electrode and received. In addition, the conductive plate disposed on the face side of the timepiece is located between the movement and the crystal. Because the distance between the movement and the crystal is sufficient to accommodate the staff supporting the hands, there is enough space inside the case to accommodate the conductive plate. The area of the conductive plate can therefore be increased, more radio waves can be reflected by the conductive plate and input to the antenna electrode, and good antenna performance can be assured.

The antenna electrode is preferably configured so that it can receive more radio waves, and is therefore as long as possible. Using an antenna with an O-shaped or C-shaped substantially annular antenna electrode, this aspect of the invention can dispose the antenna electrode around the outside edge of the conductive plate, can increase the signal reception area of the antenna compared with a rod-like antenna or an arc-shaped antenna, and can therefore improve signal reception. In addition, the outside shape of the conductive plate may be substantially the same as the shape of the inside circumference of the case. In this configuration the space on the inside circumference side of the conductive plate can be used effectively because the antenna electrode can be located around the outside edge of the timepiece.

Furthermore, because the antenna can thus be disposed around the outside edge of the conductive plate, the antenna can be easily hidden by a separate non-conductive member such as a dial ring. Problems such as the antenna being exposed at the timepiece surface and detracting from the timepiece appearance can therefore be easily avoided, and the high quality appearance of the timepiece can be maintained.

As a result, a timepiece with a wireless function having good antenna performance and a high quality appearance can be provided.

In a timepiece with a wireless function according to another aspect of the invention the antenna has an annular dielectric substrate disposed along the outside edge of the conductive plate, and the antenna electrode is disposed on the dielectric substrate.

In this aspect of the invention the antenna electrode is disposed on an annular dielectric substrate. In general, the antenna electrode must be at least as long as the wavelength of the signals to be received, and assuring sufficient antenna electrode length in a wristwatch or other small timepiece is difficult.

Therefore, by disposing the antenna electrode on a dielectric substrate, the wavelength of input RF signals can be shortened by the dielectric substrate, and RF signals of a specific wavelength can be received by an antenna electrode that is shorter than the signal wavelength. In addition, because the dielectric substrate is formed in a ring shape, it can be disposed along the outside of the conductive plate so that it does not detract from the appearance of the timepiece.

A timepiece with a wireless function according to another aspect of the invention preferably has a transparent dial for displaying time, and a solar panel that receives light and produces electrical power, and is disposed between the dial and the movement. In this aspect of the invention the conductive plate is a solar panel support substrate that supports the solar panel.

When a solar panel is included as in this aspect of the invention, the solar panel support substrate that supports the solar panel can also be used as the conductive plate that reflects RF signals, and the construction of the timepiece can be further simplified. Furthermore, by disposing the antenna along the outside of the solar panel support substrate, the solar panel can cover the entire area on the inside circumference side of the solar panel. A solar panel with a sufficiently large surface area and good photovoltaic efficiency can therefore be used.

In a timepiece with a wireless function according to another aspect of the invention the conductive plate is a dial for displaying time.

This aspect of the invention can use the dial as the conductive plate when a metal dial is used for a good appearance, and can thereby further simplify timepiece construction. In addition, because the antenna is disposed around the outside edge of the dial, problems such as indicia on the dial being hidden by the antenna are prevented, and the legibility and appearance of the dial can be balanced with good antenna performance.

In a timepiece with a wireless function according to another aspect of the invention the case has a signal reflection surface that is disposed to least one part of the end thereof on the crystal side and reflects signals entering from the crystal side to the antenna, and the conductive plate is disposed with the outside edge thereof in contact with the inside circumference surface of the case.

In this aspect of the invention a RF reflection surface is formed on one end of a conductive case. As a result, signals can be reflected by this RF reflection surface and guided to the antenna electrode, and antenna performance can be further improved. In addition, the outside edge of the conductive plate is disposed in contact with the case so that there is no gap between the conductive plate and the case, thereby achieving the same effect as when the conductive plate extends to the outside circumference side, and more radio waves can therefore reflected to the antenna electrode. The reception sensitivity of the antenna can therefore be further improved.

In a timepiece with a wireless function according to another aspect of the invention the crystal has a face part that covers the face side of the movement when the timepiece with wireless function is seen in sectional view through the thickness of the timepiece, and a side part that is rendered around the outside circumference of the face part with the end surface thereof fastened to the case, the end surface of the side part being fastened to the case at a position closer to the movement side than at least the top surface of the antenna opposing the face part.

In this aspect of the invention the end face of the side part of the crystal is closer to the movement than the top surface of the antenna, and more preferably is substantially flush with the conductive plate. With this configuration signals input from the side of the timepiece can also be received by the antenna electrode without being affected by the conductive case. The antenna electrode can therefore be made to receive more radio waves, and antenna performance can be further improved. Furthermore, this aspect of the invention can achieve the luxury feel that is unique to glass by covering a large area on the face side of the timepiece with the crystal instead of affixing the crystal to the case through a separate intervening member such as a ceramic bezel, for example, and a timepiece with a luxury appearance can be provided.

In a timepiece with a wireless function according to another aspect of the invention the antenna has an annular dielectric substrate disposed along the outside edge of the conductive plate; the antenna electrode includes a substantially annular main antenna unit disposed on the top surface of the dielectric substrate opposite the crystal, one or more coupling units that branch to the side of the dielectric substrate from one or more junction nodes disposed to part of the main antenna unit, and a power supply node that is formed contiguously to the opposite end of the coupling unit as the junction node on the bottom side of the dielectric substrate opposite the movement; the conductive plate has a through-opening passing through the conductive plate in the timepiece thickness direction at a position opposite the power supply node; and the timepiece further comprises a connection member that passes through the through-opening in the conductive plate, contacts the power supply node without contacting the conductive plate, and transmits to a reception unit that processes the reception signal based on radio waves received by the antenna.

With this aspect of the invention signals received by the main antenna unit are transmitted to the signal processing circuit through a connection member from a power supply unit disposed to the bottom of the dielectric substrate. Because the conductive plate has a through-opening opposite the power supply unit, the power supply unit and the conductive plate do not touch and the connection member does not touch the conductive plate, and signals received by the antenna electrode can be transmitted from the connection member to the signal processing circuit without escaping to the conductive plate.

In a timepiece with a wireless function according to another aspect of the invention the antenna receives circularly polarized waves.

Examples of circularly polarized waves include satellite signals transmitted from positioning information satellites such as those in the Global Positioning System (GPS), Galileo (the European satellite navigation system), and Satellite-Based Augmentation System (SBAS). Such satellite signals can be received anywhere on Earth from the positioning information satellites. Therefore, if the timepiece has a function for adjusting the time using time information carried in the satellite signal, the signals from the positioning information satellites can be reliably received anywhere in the world, and the correct time can always be maintained.

Other objects and attainments together with a fuller understanding of the invention will become apparent and appreciated by referring to the following description and claims taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows a GPS wristwatch according to a preferred embodiment of a timepiece with a wireless function according to the invention.

FIG. **2** is a sectional view of a GPS wristwatch according to a preferred embodiment of the invention.

FIG. **3** is an enlarged view of a GPS wristwatch according to a preferred embodiment of the invention.

FIG. **4** is an oblique exploded view of the GPS antenna disposed in a GPS wristwatch according to a preferred embodiment of the invention.

FIG. **5** is a block diagram showing the main hardware configuration of a GPS wristwatch according to a preferred embodiment of the invention.

FIG. **6** is a sectional view of a GPS timepiece according to a second embodiment of the invention.

FIG. **7** is an oblique exploded view of the GPS antenna disposed in a GPS wristwatch according to a second embodiment of the invention.

FIG. **8** is a sectional view of a GPS timepiece according to a third embodiment of the invention.

FIGS. **9**A and **9**B are sectional views of a part of a GPS timepiece according to another embodiment of the invention. FIG. **9**A shows a configuration in which the diameter of the solar panel support substrate is large, and FIG. **9**B shows a configuration in which the diameter of the solar panel support substrate is small.

FIG. **10** shows an example of a GPS antenna in another embodiment of the invention.

FIG. **11** shows an example of a GPS antenna in another embodiment of the invention.

FIG. **12** shows an example of a GPS antenna in another embodiment of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the present invention are described below with reference to the accompanying figures.

*First Embodiment

A first embodiment of the invention is described next with reference to FIG. **1** to FIG. **5**.

FIG. **1** shows a wristwatch with a GPS time adjustment device **1** (referred to herein as a "GPS wristwatch **1**") with a wireless function according to a preferred embodiment of the invention. FIG. **2** is a sectional view of the GPS wristwatch **1**. FIG. **3** is an enlarged view of the GPS wristwatch **1**, and FIG. **4** is an oblique exploded view of the GPS antenna disposed in the GPS wristwatch **1**. FIG. **5** shows the main hardware configuration of the GPS wristwatch **1**.

As shown in FIG. **1**, the GPS wristwatch **1** has a time display unit including a dial **2** and hands **3**. A window is formed in a part of the dial **2**, and an LCD display panel or other type of display **4** is presented in this window.

The hands **3** include a second hand, minute hand, and hour hand, and are driven through a drive mechanism including a wheel train and stepping motor as described below.

The display **4** is an LCD display panel in this embodiment of the invention, and presents positioning information such as the latitude and longitude or a city name, and other types of messages and information.

The GPS wristwatch **1** is configured so that it can receive satellite signals and acquire satellite time information from a plurality of GPS satellites **5**_a_, **5**_b_, **5**_c_, **5**_d_ orbiting the Earth on specific orbits, and can adjust the internally kept time based on the received time information.

Note that the GPS satellites **5**_a_, **5**_b_, **5**_c_, **5**_d_ are one example of positioning information satellites in the invention, and many GPS satellites are in orbit. At present, there are approximately 30 GPS satellites **5**_a_, **5**_b_, **5**_c_, **5**_d_ in orbit.

The GPS wristwatch **1** also has a crown **6** and buttons **7** and **8** for externally operating the GPS wristwatch **1**.

*Internal Configuration of a GPS Wristwatch

As shown in FIG. **2** and FIG. **3**, the GPS wristwatch **1** has a movement **110** that drives the hands **3**, and a case **10** that houses the movement **110**.

The case **10** includes a cylindrical external case member **101** and a back cover **102** that covers one of the openings in the case member **101** (the opening on the bottom side as seen in FIG. **2**).

Brass, stainless steel, titanium alloy, or other type of electrically conductive metal material is used for the case member **101** and back cover **102**. The back cover **102** is connected to the case member **101** by a screw thread. This forms a cavity **104** inside the case **10** with an open face **103** on the opposite side of the case member **101** (the top side of the case member **101** as seen in FIG. **2**). The movement **110** is held in this cavity **104**.

A signal reflection surface **105** is formed flush with the solar panel support substrate **120** described below on the end of the case member **101** where the open face **103** is formed. As described above, the case member **101** is made from an electrically conductive material, and when RF signals enter from the face or dial side of the timepiece, the incident signals can be reflected by this signal reflection surface **105**.

The movement **110** displays the time by means of the hands **3** described above and receives signals from the GPS satellites **5**_a_, **5**_b_, **5**_c_, **5**_d_, and includes a circuit board **25** populated with circuit devices (such as IC chips) for processing the time display and GPS functions, a drive mechanism **19** including a wheel train and stepping motor for driving the hands **3**, and a storage battery **24** that supplies power to other parts of the movement.

The circuit devices disposed to the circuit board **25** include a reception unit **18** for processing signals received from the GPS satellites **5**_a_, **5**_b_, **5**_c_, **5**_d_, and a control unit **20** for controlling the drive mechanism **19**.

The GPS wristwatch **1** has the solar panel support substrate **120** disposed to the open face **103** of the cavity **104**, and a solar panel **120**A and the dial **2** are disposed on the face side of the solar panel support substrate **120**.

The solar panel support substrate **120** is an electrically conductive plate made from brass, stainless steel, titanium alloy, or other electrically conductive metal material that is connected to the ground terminal of the circuit board **25**, and thus functions as a ground plate (reflector) that reflects signals entering through the crystal **130** toward the GPS antenna **11**.

The solar panel support substrate **120** is formed to a circular disk shape with a diameter slightly greater than the inside diameter of the case member **101** before being placed in the case **10**. The solar panel support substrate **120** is press fit into the case member **101**, and the outside edge of the solar panel support substrate **120** is therefore fixed tightly against the inside circumference surface of the case member **101**.

A notched part **121** (a "through-hole" according to the invention) connecting the space on the crystal **130** side with the space on the movement **110** side is formed in one location near the outside edge of the solar panel support substrate **120**, and more particularly near 9:00 o'clock in this embodiment of the invention.

The solar panel **120**A is affixed to the face side of the solar panel support substrate **120**, and power is produced from light incident to the crystal **130** side. This solar panel **120**A is connected to a charging control circuit **51** (see FIG. **5**), and the power generated by the solar panel **120**A is passed through this charging control circuit **51** and appropriately charged to the storage battery **24**.

The dial **2** is disposed to the outside surface of the solar panel **120**A. The outside diameters of the dial **2** and the solar panel **120**A are matched to the inside diameter of a dial ring **140**, the outside edge of each is disposed to the inside surface of the dial ring **140** with no gap therebetween, and the solar panel support substrate **120** cannot be seen from the outside.

The dial **2** is made from polycarbonate or other non-conductive plastic material, is transparent, and does not interfere with light passing through to the solar panel **120**A.

The hands **3** described above are disposed on the outside surface side of the dial **2** (the top as seen in FIG. **2**), and the movement **110** is disposed on the back cover side of the solar panel support substrate **120** (the bottom as seen in FIG. **2**). Disposed to the movement **110** in layers sequentially from the solar panel support substrate **120** side to the back cover **102** side are the drive mechanism **19**, circuit board **25**, and storage battery **24**. Of the circuit devices disposed to the circuit board **25**, the reception unit **18** is disposed in the middle of the circuit board **25** on the opposite side of the circuit board **25** (that is, on the back cover side) as the GPS antenna **11** and LCD display **4** in order to avoid the effects of noise. The control unit **20** is disposed to the circuit board **25** on the solar panel support substrate **120** side thereof.

The GPS antenna **11** of the GPS wristwatch **1** is disposed along the outside circumference of the solar panel support substrate **120**.

The GPS antenna **11** receives signals from the GPS satellites **5***a*, **5***b*, **5***c*, **5***d* described above, is disposed on the dial side of the solar panel support substrate **120**, and is configured so that the outside edge of the GPS antenna **11** substantially conforms to the shape of the outside edge of the solar panel support substrate **120** (see FIG. **3**). The GPS antenna **11** is described in further detail below.

The GPS wristwatch **1** has a dial ring **140** in which the GPS antenna **11** is housed.

The dial ring **140** is ring shaped with an outside diameter matching the dial **2**, and has a channel in which the GPS antenna **11** is held along the outside circumference. The inside circumference of the dial ring **140** is a conical surface that slopes toward the dial **2**, and has a scale with 60 equally spaced markers printed on this sloped surface.

A bezel **150** is disposed to the outside circumference of the dial ring **140**, and the crystal **130** that covers the hands **3** and the face of the dial **2** is disposed on the inside of the bezel **150**.

The bezel **150** is a ring with the outside circumference continuous to the outside circumference of the case member **101**, and is attached to the case member **101** of the case **10** by means of double-sided adhesive tape, adhesive, or an interlocking ridge and channel configuration rendered on opposing mating surfaces, for example. The bezel **150** holds the crystal **130** and presses and holds the dial ring **140** against the dial **2**.

The crystal **130** is thus disposed covering the dial side of the movement **110**, a solar panel support substrate **120** that functions as a ground plate is disposed between the crystal **130** and the movement **110**, and the hands **3** and GPS antenna **11** are disposed between the solar panel support substrate **120** and the crystal **130**.

The case member **101** and the back cover **102** of the case **10** in the GPS wristwatch **1** according to this embodiment of the invention are made from a metal material with outstanding appearance, and the surfaces thereof are given an appropriate surface finish.

The dial ring **140** and bezel **150** are made of non-conductive materials, the crystal **130** is also made from a non-conductive glass-like material, and these members therefore do not function as electromagnetic shields adversely affecting the GPS antenna **11** disposed to the outside circumference part of the solar panel support substrate **120** on the dial side.

*GPS Antenna

As shown in FIG. **4**, the GPS antenna **11** has a ring-shaped dielectric substrate **111** that is rectangular in section, and an antenna electrode **112** disposed to the surface thereof.

The dielectric substrate **111** has a function that shortens the signal wavelength. More specifically, the satellite signals transmitted from the GPS satellites **5***a*, **5***b*, **5***c*, **5***d* are circularly polarized waves with a frequency of 1575.42 MHz and wavelength of 19 cm, and the circumferential length of the antenna electrode **112** must be 1.0 to 1.4 times the wavelength of the received satellite signals in order to receive such satellite signals with a loop antenna. However, by disposing the antenna electrode **112** on the dielectric substrate **111**, the dielectric substrate **111** can shorten the wavelength of the satellite signals, and the shortened wavelength can be received by the antenna electrode **112**.

Note that for a dielectric substrate **111** with a relative static permittivity of ϵ_r, the signal wavelength shortening ratio is $1/(\epsilon_r)^{1/2}$. Therefore, to receive satellite signals with a wavelength of 19 cm using the antenna electrode **112** of a loop antenna with an approximately 3 cm diameter (approximately 9.4 cm circumferential length), a dielectric substrate **111** with relative static permittivity ϵ_r of 4 to 10 may be used. Examples of such materials include ceramics of which alumina (ϵ_r=8.5) is a main component, ceramics such as Micalex (ϵ_r=6.5-9.5) containing mica, glass (ϵ_r=5.4-9.9), and diamond (ϵ_r=5.68).

The height of the dielectric substrate **111**, that is, the distance (height) from the bottom surface facing the solar panel support substrate **120** to the top surface facing the crystal **130**, may be suitably set to the distance required for the solar panel support substrate **120** to function as a ground plate for the antenna electrode **112**. More specifically, if the height from the solar panel support substrate **120** to the antenna electrode **112** is from 0.05 to 0.01 times the wavelength received by the antenna electrode **112**, that is, the signal wavelength after wavelength shortening by the dielectric substrate **111**, signals reflected by the solar panel support substrate **120** can be desirably received by the antenna electrode **112**. For example, if the relative permittivity ϵ_r of the dielectric substrate **111** is 10, satellite signals with a wavelength of 19 cm are shortened to a wavelength of approximately 4.25 cm by the dielectric substrate **111**. In this configuration the antenna electrode **112** can desirably receive the signals reflected by the solar panel support substrate **120** if the distance from the solar panel support substrate **120** to the antenna electrode **112** is 0.21 cm to 0.42 cm, or 0.05 to 0.1 times the shortened wavelength. Note that in the GPS wristwatch **1** according to this embodiment of the invention the height of the dielectric substrate **111** is set to 0.3 cm.

The antenna electrode **112** can be rendered in unison with the dielectric substrate **111** by, for example, printing a copper, silver, or other conductive material on the surface of the dielectric substrate **111**, or by bending and affixing a conductive metal plate of copper or silver, for example, on the surface of the dielectric substrate **111**. Note, further, that a pattern may be rendered on the surface of the dielectric substrate **111**.

The antenna electrode **112** includes the main antenna unit **113**, a coupling unit **114**, and a power supply unit **115**.

The main antenna unit **113** is the ring-shaped part disposed on the surface of the dielectric substrate **111**, and receives signals entering through the crystal **130** or reflected by the solar panel support substrate **120**. A junction node **116** is formed at a place on the inside circumference part of the main antenna unit **113**, and the coupling unit **114** is rendered extending from this junction node **116** to the inside circumference side of the dielectric substrate **111**. The coupling unit **114** is formed in the circumferential direction along the inside circumference side of the dielectric substrate **111**. The distal end of the coupling unit **114**, that is, the opposite end as the end connected to the junction node **116**, extends toward the bottom of the dielectric substrate **111**, and the power supply unit **115** connected to the coupling unit **114** is formed on the bottom side of the dielectric substrate **111**.

As shown in FIG. **2**, the power supply unit **115** is formed at a position opposite the notched part **121** of the solar panel support substrate **120** at the 9:00 o'clock position, and the end part of a connection pin **61** (rendering the connection member of the invention) passing through the notched part **121** contacts the power supply unit **115** at one point (power supply node **117**). The length from the junction node **116** through the coupling unit **114** to the power supply node **117** is approximately ¼ of the wavelength of the signals received by the GPS antenna **11**, and is, for example, 1.06 cm when the dielectric substrate **111** has a relative permittivity ϵ_r of 10.

The connection pin **61** that touches the power supply node **117** of the power supply unit **115** is supported so that it can rise freely in a connector base part **62** standing at the 9:00 o'clock position. By thus disposing the connection pin **61** at 9:00 o'clock, structural interference with the crown **6** disposed at 3:00 o'clock and the buttons **7** and **8** disposed at 2:00 o'clock and 4:00 o'clock as external operating members can be avoided.

In addition, the connection pin **61** and connector base part **62** are electrically connected, and the connector base part **62** is connected to the reception unit **18**. The connector base part **62** is basically cylindrically shaped, and a coil spring or other urging member disposed inside the cylinder urges the connection pin **61** to the power supply unit **115** side. As a result, the connection pin **61** is pressed against the power supply node **117**, and the connection between the connection pin **61** and power supply node **117** is maintained even when the GPS wristwatch **1** is subject to shock.

As shown in FIG. **4**, the connector base part **62** is connected to a connection node **251** in the middle of the circuit board **25** by a wire lead, and is connected at this connection node **251** to the reception unit **18** disposed on the back cover **102** side of the circuit board **25**. Note that in order for a single wavelength loop antenna such as the GPS antenna **11** in this embodiment of the invention to efficiently receive circularly polarized waves, the connection node **251** is preferably located in the middle part of the circuit board **25**.

On the other hand, when the connection node **251** is thus disposed in the middle of the circuit board **25**, the wiring becomes longer and signal loss increases. In order to solve this problem, a low noise amplifier (LNA) may be disposed between the GPS antenna **11** and the reception unit **18**, and more particularly between the GPS antenna **11** and a filter (SAW) **31** described below (see FIG. **5**), to compensate for signal loss.

Note that the method of connecting the connector base part **62** and the reception unit **18** is not limited to the foregoing. For example, the connector base part **62** may be connected to a printed circuit on the circuit board **25** and connected to the reception unit **18** through this printed circuit.

In this embodiment of the invention the solar panel support substrate **120** also serves as a ground plate and functions as the ground plate of the GPS antenna **11**.

In general, the antenna ground plate is as large as possible, and the length of one side if the ground plate is rectangular or the outside diameter (the diameter of the outside circumference) if the ground plate is round is preferably at least ¼ of the wavelength of the signals that are sent and received by the antenna.

In this embodiment of the invention the outside diameter of the solar panel support substrate **120** used as the ground plate is preferably 48 mm or more in order to receive signals from the GPS satellites. However, the outside diameter of the dial **2** used in a wristwatch is typically 35 mm, and the required 48 mm diameter cannot be obtained. To compensate for this deficiency, this embodiment of the invention uses a configuration that has a signal reflection surface **105** formed flush with the solar panel support substrate **120** at the top end part of the case member **101**, and this signal reflection surface **105** and solar panel support substrate **120** together function as the ground plate.

As described above, the solar panel support substrate **120** is press fit into the case member **101**, rendering the outside circumference edge of the solar panel support substrate **120** and the inside circumference surface of the case member **101** in contact with no gap between the solar panel support substrate **120** and case member **101**, thereby increasing the area that can be made to function as the ground plate. As a result, incident signals can be more efficiently reflected to the GPS antenna **11**, and antenna characteristics can be improved.

Furthermore, the signal reflection surface **105** of the case member **101** is rendered flush with the solar panel support substrate **120** in this embodiment of the invention, but the invention is not so limited. More specifically, if the distance from the signal reflection surface **105** to the top of the dielectric substrate **111** is between 0.05 to 0.01 times the wavelength (the signal wavelength after wavelength shortening by the dielectric substrate **111**) of the signals received by the antenna electrode **112**, signals reflected by the signal reflection surface **105** can be desirably received by the main antenna unit **113**.

Note that a LCD panel is disposed on the back side of the dial **2** as the display **4**, and this LCD panel is covered by a shield plate to shield the effects of noise. By using the solar panel support substrate **120** as a ground plate in this configuration, a shield effect is also achieved around the display **4**.

Furthermore, the stepping motor of the drive mechanism **19** is also a source of noise, but because the drive mechanism **19** is located on the opposite side of the solar panel support substrate **120** as the GPS antenna **11**, it is shielded by the solar panel support substrate **120** and its effect on the GPS antenna **11** is thereby suppressed.

Furthermore, because the case **10** including the back cover **102** and case member **101** is metal, the effect of the user's arm on the GPS antenna **11** can also be avoided. More specifically, if the case **10** is a plastic case, the resonance frequency of the antenna differs when the timepiece is worn and when it is not worn due to the effect of the nearby arm, resulting in an undesirable performance difference. However, because the case **10** is metal in this embodiment of the invention, the effect of the arm can be avoided by the shield effect of the metal case, there is substantially no difference in antenna performance in this embodiment when the timepiece is worn and when it is not worn, and stable reception performance can be achieved.

*Circuit Configuration of a GPS Wristwatch

The circuit configuration of the GPS wristwatch **1** according to this embodiment of the invention is described next. As shown in FIG. **5** the GPS wristwatch **1** has a GPS antenna **11**, filter (SAW) **31**, reception unit **18**, display control unit **40**, and power supply unit **50**.

The filter (SAW) **31** is a bandpass filter that extracts 1.5 GHz satellite signals. A low noise amplifier (LNA) as described above may also be disposed to improve reception sensitivity between the GPS antenna **11** and the filter **31**.

Note, further, that the filter (SAW) **31** may be incorporated in the reception unit **18**.

The RF unit **27** includes a PLL (phase locked loop) circuit **34**, an IF filter **35**, a VCO (voltage controlled oscillator) **41**, an A/D converter **42**, a mixer **46**, a low noise amplifier (LNA) **47**, and an IF (intermediate frequency) amplifier **48**.

The satellite signal extracted by the SAW filter **31** is amplified by the LNA **47**, then mixed by the mixer **46** with a signal from the VCO **41** and down-converted to a signal in the intermediate frequency band. The IF signal mixed by the mixer **46** passes through the IF amplifier **48** and IF filter **35**, and is converted to a digital signal by the A/D converter **42**.

The baseband unit **30** includes a DSP (digital signal processor) **39**, CPU (central processing unit) **36**, and SRAM (static random access memory) **37**. A TXCO (temperature-compensated crystal oscillator) **32** and flash memory **33** are also connected to baseband unit **30**.

Digital signals from the A/D converter **42** of the RF unit **27** are input to the baseband unit **30**, which based on a control signal processes the satellite signals and acquires the satellite time information and positioning information.

Note that the clock signal for the PLL circuit **34** is generated by the TXCO **32**.

The display control unit **40** includes a control unit (CPU) **20** and a drive circuit **43** that drives the hands **3** and the LCD display **4**.

The hardware components of the control unit **20** include a real-time clock (RTC) **20**A and storage unit **20**B.

The real-time clock **20**A keeps the internal time information using a reference signal output from a crystal oscillator.

The storage unit **20**B stores time data and positioning data output from the reception unit **18**. Time difference data correlated to the positioning information is also stored in the storage unit **20**B, and the local time at the current location can be calculated from the time difference data and the internal time information kept by the real-time clock **20**A.

The GPS wristwatch **1** according to this embodiment of the invention can automatically adjust the time by means of the reception unit **18** and the display control unit **40** based on the signals received from the GPS satellites.

The power supply unit **50** includes the solar panel **120**A, charging control circuit **51**, storage battery **24**, a first regulator **52**, a second regulator **53**, and a voltage detection circuit **54**.

The storage battery **24** supplies drive power to the display control unit **40** through the first regulator **52**, and supplies drive power to the reception unit **18** through the second regulator **53**.

The solar panel **120**A supplies power to the storage battery **24** through the charging control circuit **51**, and charges the storage battery **24**.

The voltage detection circuit **54** monitors the voltage of the storage battery **24**, and outputs to the control unit **20**. The control unit **20** can therefore determined the storage battery **24** voltage and control the reception process.

As described above, the GPS wristwatch **1** according to a first embodiment of the invention has a solar panel support substrate **120** that functions as a ground plate between the crystal **130** and the movement **110**. In addition, a GPS antenna **11** with a dielectric substrate **111** and a ring-shaped antenna electrode **112** formed on the surface of the dielectric substrate **111** is disposed between the solar panel support substrate **120** and the crystal **130**.

As a result, satellite signals entering from the crystal side can be reflected by the solar panel support substrate **120** with a relatively large surface area disposed on the crystal **130** side and input to the antenna electrode **112**, thereby assuring good antenna performance. In addition, because the antenna electrode **112** rendering a ring-shaped main antenna unit **113** is formed on the ring-shaped dielectric substrate **111**, the signal reception area of the antenna electrode **112** can be increased and the reception sensitivity of the antenna can be improved.

Furthermore, because the antenna electrode **112** can be rendered with a large signal reception area, the dielectric substrate **111** can be made from a wider selection of materials and designing the GPS antenna **11** can be made easier. More specifically, the antenna electrode **112** must be at least as long as the wavelength of the signals to be received, and if the length of the antenna electrode **112** is short, a dielectric substrate **111** with relative static permittivity great enough to shorten the signal wavelength according to length of the antenna electrode **112** is required. This narrows the selection of materials usable for the dielectric substrate **111**, and increases cost. However, by using a ring-shaped antenna electrode **112** as described in this embodiment of the invention, sufficient circumferential length can be assured and the dielectric substrate **111** can be selected from a wider range of materials. A suitably lower cost dielectric substrate **111** can therefore be selected, which is beneficial for production.

In addition, a metal case member **101** and back cover **102** can be used for the case **10**, and a high quality appearance can be achieved for the timepiece.

The GPS wristwatch **1** according to this embodiment of the invention also uses a solar panel support substrate **120** as a conductive plate supporting the solar panel **120**A.

With this configuration the solar panel support substrate **120** can be used as a ground plate and as a support substrate for the solar panel **120**A, and using a dedicated substrate to support the solar panel **120**A and a separate substrate that functions as a conductive plate is not necessary. An increase in the parts count can therefore be suppressed and the configuration can be simplified.

A signal reflection surface **105** is also formed flush with the solar panel support substrate **120** on the open face **103** side of the case member **101** of the GPS wristwatch **1**. The solar panel support substrate **120** is press fit into the inside circumference side of the case member **101**, thereby disposing the outside edge thereof against the inside circumference surface of the case member **101**.

As a result, the ground plate can be rendered by the signal reflection surface **105** and the solar panel support substrate **120** together. In addition, because there is no gap between the signal reflection surface **105** and solar panel support substrate **120**, signals can be reflected without leaking from the crystal **130** side to the movement **110** side.

As also described above, the antenna electrode **112** of the GPS antenna **11** includes a ring-shaped main antenna unit **113** disposed on the top surface of the ring-shaped dielectric substrate **111**, a coupling unit **114** that follows the inside surface of the dielectric substrate **111** from a junction node at one point on the inside circumference edge of the main antenna unit **113**, and a power supply unit **115** that is contiguous to the opposite end of the coupling unit **114** as the junction node **116** and is formed on the bottom side of the dielectric substrate **111**. A notched part **121** is disposed in the solar panel support substrate **120** at a position opposite the power supply unit **115**, and a connection pin **61** is disposed passing through the notched part **121** and urged from the movement **110** side toward the power supply point **117**.

As a result, contact between the power supply unit **115** and the solar panel support substrate **120**, and contact between the connection pin **61** and the solar panel support substrate **120**, can be prevented while the antenna electrode **112** and the reception unit **18** of the circuit board **25** can be reliably electrically connected by means of the connection pin. In addition, because the connection pin **61** is urged to the power supply point **117** side, the connection pin **61** and power supply point **117** can be held desirably connected even when the timepiece is subject to shock.

The reception unit **18** is disposed on the back cover **102** side of the circuit board **25**, and the solar panel support substrate **120** used as a ground plate is disposed between the reception unit **18** and the GPS antenna **11**. As a result, the solar panel support substrate **120** functions as a shield against noise output from the internal clock of the reception unit **18**. The GPS antenna **11** is therefore not exposed to the effects of noise from the reception unit **18**, and antenna performance can be improved.

The GPS antenna **11** is disposed on the face side of the dial **2**, and the surrounding dial ring **140** and bezel **150** are made from a non-conductive material. As a result, the GPS antenna **11** is not subject to electromagnetic shielding even if the case **10** is made from a metal material with an outstanding appearance, and good antenna performance can be assured.

In addition, because the case member **101** and back cover **102** of the case **10** are metal, antenna matching is not affected by the GPS wristwatch **1** being worn on the wrist, the difference between antenna characteristics when the timepiece is worn and not worn is less, and stable signal reception is possible.

*Embodiment 2

A GPS wristwatch according to a second embodiment of the invention is described next. FIG. **6** is a sectional view of a GPS timepiece according to a second embodiment of the invention. FIG. **7** is an oblique exploded view of the timepieces antenna in the second embodiment.

Note that the configuration of the GPS wristwatch **1**A according to the second embodiment of the invention is substantially the same as the first embodiment described above, and further detailed description of common components is omitted below for brevity.

In the first embodiment the solar panel support substrate **120** functions as a conductive plate according to the invention and the solar panel support substrate **120** reflects incident signals to the GPS antenna **11**.

In this second embodiment of the invention as shown in FIG. **6** and FIG. **7**, the solar panel **120**A and solar panel support substrate **120** are omitted, and the dial **2**A functions and the conductive plate of the invention, that is, as the ground plate.

More specifically, the dial **2**A of the GPS wristwatch **1**A according to the second embodiment of the invention is made slightly larger than the inside dimensions of the case member **101** and is press fit to the inside circumference of the case member **101**. The dial **2**A is made from brass, stainless steel, titanium alloy, or other type of metal. The surface of the dial **2**A may be finished with an appropriate surface process such as painting, plating, or sputtering in order to improve the appearance.

In this configuration the dial **2**A is disposed to the open face **103** of the case member **101**, functions as a ground plate, and reflects signals entering from the crystal **130** to the main antenna unit **113** of the antenna electrode **112** to improve antenna performance.

This embodiment of the invention has the same effects as the first embodiment described above. More specifically, the dial **2**A that functions as a ground plate is disposed between the crystal **130** and the movement **110**, and a GPS antenna **11** with a dielectric substrate **111** and antenna electrode **112** formed on the surface of the dielectric substrate **111** is disposed between the dial **2**A and the crystal **130**.

As a result, satellite signals entering from the crystal side can be reflected by the dial **2**A with a relatively large surface area disposed on the crystal **130** side and input to the antenna electrode **112**, thereby assuring good antenna performance. In addition, because the antenna electrode **112** rendering a ring-shaped main antenna unit **113** is formed on the ring-shaped dielectric substrate **111**, the signal reception area of the antenna electrode **112** can be increased and the reception sensitivity of the antenna can be improved.

Furthermore, because the dial **2**A needs sufficient conductivity to function as a ground plate, it can be made from a metal material with a high quality appearance. In addition, because the GPS antenna **11** is disposed around the outside of the dial **2**A, the display area of the dial **2**A will not be hidden even if the GPS antenna **11** is covered with the dial ring **140**. As a result, the appearance of the GPS wristwatch **1**A can be improved.

The construction of the GPS wristwatch **1**A in this embodiment of the invention can also be simplified because the dial **2**A also functions as the ground plate.

*Embodiment 3

A GPS wristwatch **1**B according to a third embodiment of the invention is described next. FIG. **8** is a sectional view showing the configuration of the GPS wristwatch **1**B according to the third embodiment of the invention.

Note that the configuration of the GPS wristwatch **1**B according to the third embodiment of the invention is substantially the same as the first embodiment described above, and further detailed description of common components is omitted below for brevity.

In the GPS wristwatches **1** and **1**A according to the first and second embodiments of the invention described above, a bezel **150** is disposed to one side of the case member **101** with the bezel **150** holding the crystal **130**. In this third embodiment of the invention as shown in FIG. **8**, however, the crystal **130**A is disposed directly to the case member **101**.

The crystal **130**A used in this embodiment of the invention is manufactured to a bowl-shaped configuration having a face part **131** that covers the face of the timepiece, and a cylindrical side part **132** formed around the outside edge of the face part **131**, by cutting and polishing a glass plate. A ridge and channel part is formed on the end of the side part **132** of the crystal **130**A, and the crystal **130**A is attached to the case **10** by fitting this ridge and channel part to a matching ridge and channel part formed on the end of the case member **101**, thereby covering the side surface of the GPS antenna **11** from the face. The end face of the side part **132** of the crystal **130**A is formed so that it extends to the side of the movement **110** from the top of the GPS antenna **11** where the main antenna unit **113** is disposed. More specifically, the end of the side part **132** is formed to be at substantially the same elevation as the surface of the solar panel support substrate **120** when affixed to the case member **101**.

Note that as in the first and second embodiments of the invention the GPS antenna **11** cannot be seen from the outside in this third embodiment of the invention because the GPS antenna **11** is covered by the dial ring **140**, but printing may be applied to the inside surface of the crystal **130**A at a position overlapping the GPS antenna **11** so that the GPS antenna **11** cannot be seen from the outside. A non-conductive ink is used for printing in this configuration so that the reception performance of the antenna is not affected.

The GPS wristwatch **1**B according to the third embodiment of the invention also has a charging coil **55** disposed opposite the back cover **102** so that the battery can be charged from an external charger by means of electromagnetic induction. To enable effective charging by means of electromagnetic induction, the back cover **102** has an annular first back cover part **102**A made of metal, and a disk-shaped second back cover part **102**B made of glass that is held by the first back cover part **102**A. Note that the storage battery **24** is charged by both the charging coil **55** and the solar panel **120**A in this configuration, but the battery may be charged using only the solar panel **120**A as described in the first embodiment above, or by only the charging coil **55**. When only the charging coil **55** is used for charging, the dial **2**A may be used as a conductive plate as described in the second embodiment above.

In addition to the effects of the first embodiment described above, this embodiment of the invention reduces the parts count by the omission of the bezel **150**. In addition, while the surface of a ceramic bezel **150** is easily scratched and the appearance therefore deteriorates over time, this deterioration in appearance over time can be prevented in this embodiment of the invention because the case member **101** is covered by scratch-resistant glass.

In addition, this embodiment of the invention can achieve the luxury feel that is unique to glass by covering the entire face side of the GPS wristwatch **1** with the crystal **130**A instead of using a crystal **130** that is disposed through a separate intervening member such as the bezel **150**.

Furthermore, because the crystal **130**A is formed to cover the top from the sides of the GPS antenna **11**, signals input from the side of the GPS wristwatch **1**B can also be received by the GPS antenna **11**.

*Other Embodiments

The invention is not limited to the embodiments described above and can be varied in many ways without departing from the scope of the accompanying claims.

For example, the first to third embodiments above describe configurations in which the outside diameter of the solar panel support substrate **120** and dial **2**A used as a conductive plate substantially matches the outside edge of the GPS antenna **11**, but the invention is not so limited. More particularly, as shown in FIG. **9**A, the outside diameter of the solar panel support substrate **120** used as a conductive plate may be further increased, and the GPS antenna **11** may be disposed on the inside circumference side of the outside edge of the solar panel support substrate **120**. In this configuration a shoulder **106** that holds the outside edge of the solar panel support substrate **120** is disposed to the case member **101**, and the solar panel support substrate **120** is disposed substantially flush with the signal reflection surface **105** of the case member **101** by press fitting the solar panel support substrate **120** into this shoulder **106**.

Further alternatively, the outside diameter of the solar panel support substrate **120** used as the conductive plate may be reduced as shown in FIG. **9**B. In this configuration the signal reflection surface **105** of the case member **101** is extended to the inside of the timepiece, and the outside edge of the solar panel support substrate **120** is fit to the inside circumference surface rendered by the distal end face **107** of the signal reflection surface **105**. As a result, there is no gap between the signal reflection surface **105** and the solar panel support substrate **120**, and good antenna performance can be achieved.

Each of the first to third embodiments above describes a GPS wristwatch **1**, **1**A, **1**B that is substantially round in plan view and has a ring-shaped GPS antenna **11** conforming to the shape of the wristwatch, but the invention is not so limited. For example, some GPS wristwatches with a digital display are substantially square or rectangular when seen in plan view. A ring-shaped GPS antenna **11** may be disposed inside such a timepiece, or a rectangular GPS antenna **11**A matching the shape of the timepiece may be used instead. By using such a rectangular GPS antenna **11**A, the circumferential length of the antenna electrode **112** can be increased compared with a configuration having a ring-shaped GPS antenna **11** disposed in a rectangular timepiece, and better antenna performance can be achieved. In addition, by using a rectangular GPS antenna **11**A in a rectangular timepiece, the space inside the timepiece can be used more effectively to, for example, increase the display area of the digital display.

Furthermore, a configuration having the coupling unit **114** disposed along the inside surface of the dielectric substrate **111** from the junction node **116** of the main antenna unit **113** is described by way of example as the GPS antenna **11** above, but the invention is not so limited. For example, as shown in the GPS antenna **11**B in FIG. **11**, a configuration having the junction node **116** disposed to the outside circumference side of the main antenna unit **113**, and the coupling unit **114** formed extending from this junction node **116** to the outside circumference side of the dielectric substrate **111** and continuing circumferentially along the outside surface is also conceivable.

Yet further, the first to third embodiments above describe a GPS antenna **11** having a single power supply unit **115**, but a GPS antenna **11**C having a plurality of power supply units **115** as shown in FIG. **12** is also conceivable. The GPS antenna **11**C shown in FIG. **12** has two power supply units **115**A and **115**B disposed to the ring-shaped main antenna unit **113**. In this configuration power supply unit **115**A and power supply unit **115**B are disposed so that the phase difference therebetween is 90°, rendering two orthogonal power supply points. There are therefore also two connection pins **61** corresponding to the two power supply units **115**A and **115**B of this GPS antenna **11**C, and the satellite signals are transmitted from these two connection pins **61** to the circuit board **25**. The circuit board **25** executes a reception process for circularly polarized waves by adjusting the phase difference of these two paths and inputting the signals to the reception unit **18**.

A loop antenna having a ring-shaped main antenna unit **113** is described as an example of the GPS antenna **11** above, but the invention is not so limited. The main antenna unit **113** may, for example, be C-shaped. Circularly polarized waves can also be received with this configuration by rendering the junction node **116** connected to the coupling unit **114** at a position ¼ wavelength from one end of the C-shaped main antenna unit.

A connection pin **61** is described as an example of a connection member that contacts the power supply unit **115** above, but the invention is not limited to such pin members.

For example, a contact plate rendered like a flat spring may be used as the connection member. In such a configuration the urging force of the flat spring assures that the contact plate contacts the power supply point **117** with a specific contact pressure.

A combination timepiece having both hands **3** and a display **4** is described by way of example as the GPS wristwatch **1** according to the invention, but the invention is not so limited. The invention can also be used advantageously in a digital timepiece having only a display, for example.

The invention is also not limited to wristwatches, and may be used in pocket watches and other types of timepieces, cell phones, digital cameras, portable digital assistant devices, and other types of devices with an electronic timepiece function.

The foregoing embodiments are described with reference to a GPS satellite as an example of a positioning information satellite, but the positioning information satellite of the invention is not limited to GPS satellites and the invention can be used with Global Navigation Satellite Systems (GNSS) such as Galileo (EU), GLONASS (Russia), and Beidou (China), and other positioning information satellites that transmit satellite signals containing time information, including the SBAS and other geostationary or quasi-zenith satellites.

The invention is also not limited to receiving satellite signals from positioning information satellites, and may be used with short-range receivers for receiving circularly polarized RF tags that use the 900 MHz band, for example.

The invention is also not limited to receiving circularly polarized waves, and may be used to receive linearly polarized waves.

The foregoing embodiments also have a dial ring **140** as a ring member covering the GPS antenna **11**, but the invention is not so limited. More specifically, the ring member may be a member without indicia, and the inside surface may be perpendicular to the dial **2** or otherwise shaped instead of sloped.

The ring member is also not essential to the invention and a separate ring member can be omitted if the inside circumference of the bezel **150** protrudes to the inside and covers the GPS antenna **11**.

The foregoing embodiments describe configurations in which a metal dial **2** functions as a ground plate or the solar panel support substrate **120** for the solar panel functions as a ground plate, but a discrete metal plate that is not also used as another functional member may be used instead and fit to the inside circumference surface of the case member **101**.

The material of the conductive plate is also not limited to a metal material, and a metallic coating may be rendered on the surface of a plate made from a non-metallic material. Further alternatively, the conductive plate is not limited to a single contiguous member, and may be rendered from a plurality of small pieces forming a contiguous plate. Yet further alternatively, a substantially flat metal mesh material may be used.

Except for the GPS antenna **11**, the members (bezel **150**, crystal **130**, dial ring **140**) disposed more to the outside than the dial **2** or solar panel support substrate **120** used as the ground plate in the foregoing embodiments are made from a non-conductive material such as plastic or ceramic to avoid creating an electromagnetic shield, but it is not necessary to render all of these parts from non-conductive materials, and metallic materials may be used for parts of these elements. However, because electromagnetic shielding of the antenna increases with the increase in metallic materials, care must be taken to ensure antenna performance.

Note that metal may be used for the hands **3** because the area of the hands **3** is small, but the hands **3** are preferably made from a non-conductive material to avoid affecting the antenna.

Furthermore, the GPS antenna **11** has a ring-shaped dielectric substrate **111** in the foregoing embodiments, but a configuration not having a dielectric substrate **111** is also conceivable. More specifically, when receiving circularly polarized waves with a sufficiently short wavelength, the signals can be received directly by the antenna electrode **112** without shortening the signal wavelength. For such applications a configuration that does not have a dielectric substrate **111** and has only an antenna electrode **112**, or a configuration that renders the antenna electrode **112** on an annular block that does not have a wavelength shortening function, for example, may be used.

Although the present invention has been described in connection with the preferred embodiments thereof with reference to the accompanying drawings, it is to be noted that various changes and modifications will be apparent to those skilled in the art. Such changes and modifications are to be understood as included within the scope of the present invention as defined by the appended claims, unless they depart therefrom.

While the invention has been described in conjunction with several specific embodiments, it is evident to those skilled in the art that many further alternatives, modifications and variations will be apparent in light of the foregoing description. Thus, the invention described herein is intended to embrace all such alternatives, modifications, applications and variations as may fall within the spirit and scope of the appended claims.

What is claimed is:

1. A timepiece with a wireless function, comprising:

a movement for displaying time;

a conductive case that holds the movement;

a crystal that is disposed on the face side of the case and covers the face side of the movement;

a dial that is made of non-conductive material;

a conductive plate that is electrically conductive, disposed between the movement and the dial, and reflects radio waves; and

an antenna that has a substantially annular, conductive antenna electrode, and is disposed along the outside edge of the conductive plate;

wherein the antenna is disposed between the dial and the crystal as seen in a lateral view.

2. The timepiece with a wireless function described in claim **1**, wherein:

the antenna has an annular dielectric substrate disposed along the outside edge of the conductive plate, a part of the annular dielectric substrate being disposed between the dial and the crystal as seen in the lateral view, and

the antenna electrode is disposed on the dielectric substrate.

3. The timepiece with a wireless function described in claim **1**, further comprising:

a solar panel that receives light and produces electrical power, and is disposed between the dial and the movement;

wherein the conductive plate further functions as a solar panel support substrate that supports the solar panel; and

wherein the dial is transparent.

4. The timepiece with a wireless function described in claim **1**, wherein:

the case has a signal reflection surface that is disposed to least one part of the end thereof on the crystal side and reflects signals entering from the crystal side to the antenna; and

the conductive plate is disposed with the outside edge thereof in contact with the inside circumference surface of the case.

5. The timepiece with a wireless function described in claim **1**, wherein:

the crystal has a face part that covers the face side of the movement when the timepiece with wireless function is seen in section view through the thickness of the timepiece, and a side part that is rendered around the outside circumference of the face part with an end surface thereof fastened to the case,

the end surface of the side part being fastened to the case at a position closer to a movement side than at least the top surface of the antenna opposing the face part.

6. The timepiece with a wireless function described in claim **1**, wherein:

the antenna has an annular dielectric substrate disposed along the outside edge of the conductive plate;

the antenna electrode includes a substantially annular main antenna unit disposed on the top surface of the dielectric substrate opposite the crystal,

one or more coupling units that branch to the side of the dielectric substrate from one or more junction nodes disposed to part of the main antenna unit, and

a power supply node that is formed contiguously to the opposite end of the coupling unit as the junction node on the bottom side of the dielectric substrate opposite the movement;

the conductive plate has a through-opening passing through the conductive plate in the timepiece thickness direction at a position opposite the power supply node; and

the timepiece further comprises a connection member that passes through the through-opening in the conductive plate, contacts the power supply node without contacting the conductive plate, and transmits to a reception unit that processes the reception signal based on radio waves received by the antenna.

7. The timepiece with a wireless function described in claim **1**, wherein:

the antenna receives circularly polarized waves.

8. The timepiece with a wireless function described in claim **1**, further comprising:

a dial ring that is made of non-conductive material and has a channel in which the antenna is held.

9. The timepiece with a wireless function described in claim **1**, further comprising:

a bezel that is made of non-conductive material and covers the antenna.

10. The timepiece with a wireless function described in claim **1**, wherein:

the antenna electrode is configured to receive radio waves reflected by the conductive plate.

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